1-16, 18-44, 47-52

News

41076

…et Halley Flyby Mission

…mission to Halley should be designed to maximize the …e in terms of the objectives of the comet exploration …m set down by the NASA Comet Science Working … and the Space Science Board (*Report of the Comet …e Working Group*, NASA TM 80543, 1979; *Strategy … Exploration of Primitive Solar System Bodies—Aster… Comets, and Meteoroids: 1980–1990*, Committee on …ry and Lunar Exploration, Space Science Board, …gton, DC, 1980). In order of priority, these objectives …

…determine the chemical nature and physical structure … nuclei and to characterize the changes that occur as … of time and orbital position;

…haracterize the chemical and physical nature of the …eres and ionospheres of comets, as well as the pro… that occur in them, and to characterize the develop… he atmospheres and ionospheres as functions of … orbital position; and

…determine the nature of comet tails and of the pro… which they are formed and to characterize the in… of comets with the solar wind.

… particular context of a Halley mission, these can … as follows:

…etermine the appearance of the nucleus of Comet … infer (a) size and shape, (b) structure, (c) hetero…

…termine the chemical composition and physical … and nonvolatile material emitted by …

…aracterize the processes that occur in bright, active … Halley and new comets), including (a) chemical, … and plasma processes in the atmosphere and iono… (b) dynamics of dust and ice grains; (c) interaction … the solar wind and the coma; and (d) structure and … of the tails.

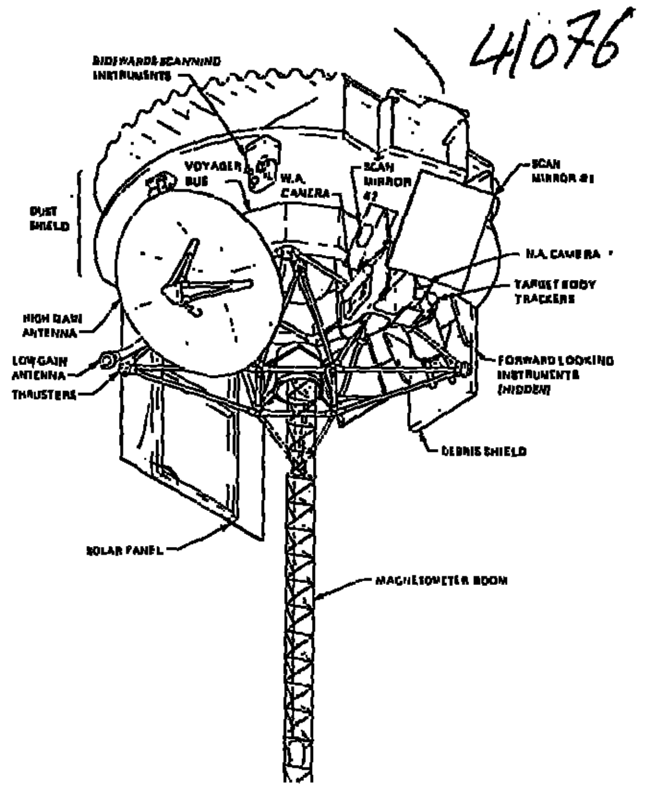

Fig. 1. The Halley Intercept Mission spacecraft.

These aims lead to a number of practical requirements on any mission to Halley:

(1) Accurate targeting of the spacecraft to a preselected point within the zone of parent molecules next to the nucleus.

(2) Good imaging of the nucleus.

(3) An 'observatory phase' during which imaging of the tail and coma at progressively increasing spatial resolutions will be obtained.

(4) Sufficiently long observation time for in situ measurements to cover the full 10^7-km scale of phenomena at Halley.

The Halley Intercept Mission is based on a three-axis-stabilized spacecraft. This allows significantly better imaging than can be achieved with most spinning spacecraft. A framing camera on a fixed-attitude spacecraft is the best means of achieving an observatory phase during which sequences of pictures are taken of the comet's tails and extended coma. Furthermore, with a framing camera, onboard optical navigation can deliver the spacecraft to the selected point in the target plane with an accuracy of ±90 km (1 σ); the most optimistic estimate of delivery accuracy without onboard navigation is ±500 km (Giotto). With optical navigation, it is thus possible to make sure the spacecraft passes through the zone of parent molecules which extends ~10^3 km from the nucleus, on the sunlit side, at a great enough distance to avoid smear in the highest resolution pictures.

The Halley Intercept spacecraft (see figure) has a total mass of ~1600 kg, of which 300–400 kg will be allotted to the dust shield and ~125 kg to the science payload. A possible science payload is summarized in the table.

Halley goes through perihelion (0.6 AU) on February 9, 1986. A major advantage of the Halley Intercept Mission is that it can intercept the comet either before or after perihelion.—*PMB*

Halley Intercept Mission Typical Payload

Instrument	Mass, kg	Power, W	Data, kbps
Neutral mass spectrometer	6	5	2
Ion mass/velocity spectrometer	7	11	3
Electron analyzer	4	3	2
Magnetometer	3	5	1
Plasma wave analyzer	4	7	1
Dust composition analyzer	11	12	3
Dust counter	3	3	1
Remote sensor	12	8	2
Subtotal	50	54	15
Imaging	76	38	90
Total	126	92	105

EOS

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Cover. This image of the terrain of the conterminous United States was composed by an Optronics system from about 550,000 …verage elevation points provided by the U.S. Department of De…ense. A contour interval of 121 m was used between 15- and 500-m …levation, and one of 619 m above that elevation. The outline of the …onterminous United States is not precise because the contours be…in at an altitude of 15 m.

Well-known geologic features like the Mississippi Embayment, the Snake River Plain, the Basin and Range, and various mountain ranges are readily recognizable. Of perhaps greater interest are features and characteristics not previously recognized or reported in the literature. For example, an arcuate zone that includes Lakes Ontario and Erie extends from the St. Lawrence Valley to the west border of Michigan. It corresponds approximately to part of a predicted zone of brittle deformation caused by the Pleistocene ice load. The highlands of the western United States exhibit a blocklike outline to the north and east, being delimited by a boundary extending from south central Texas to northeast Iowa and thence west to the Olympic Peninsula of Washington. The east boundary is the dividing line between typical eastern and western topographic expression; it is also the approximate location of seismicity associated with the Nemaha Uplift. The central and southern Appalachians show a surprisingly angular outline, particularly in contrast to the Appalachian features of the northeast. Much of the complex structure of the west coast of the United States is clearly depicted. Analyses of terrain data of the eastern United States suggest a correlation between regions of seismicity and certain of the terrain features.

The scale of the map that is shown is approximately 1:30,000,000. Terrain maps compiled at scales as large as 1:1,000,000 show many smaller features, usually extensive linear trends or areas of terrain of distinctive morphology. These features are thought to be surface expressions of underlying geologic structures. The digital terrain data are a new and virtually unexploited information source and should be useful in a wide variety of earth science investigations. (Photo cour…

Earth Radiation Budget Satellite

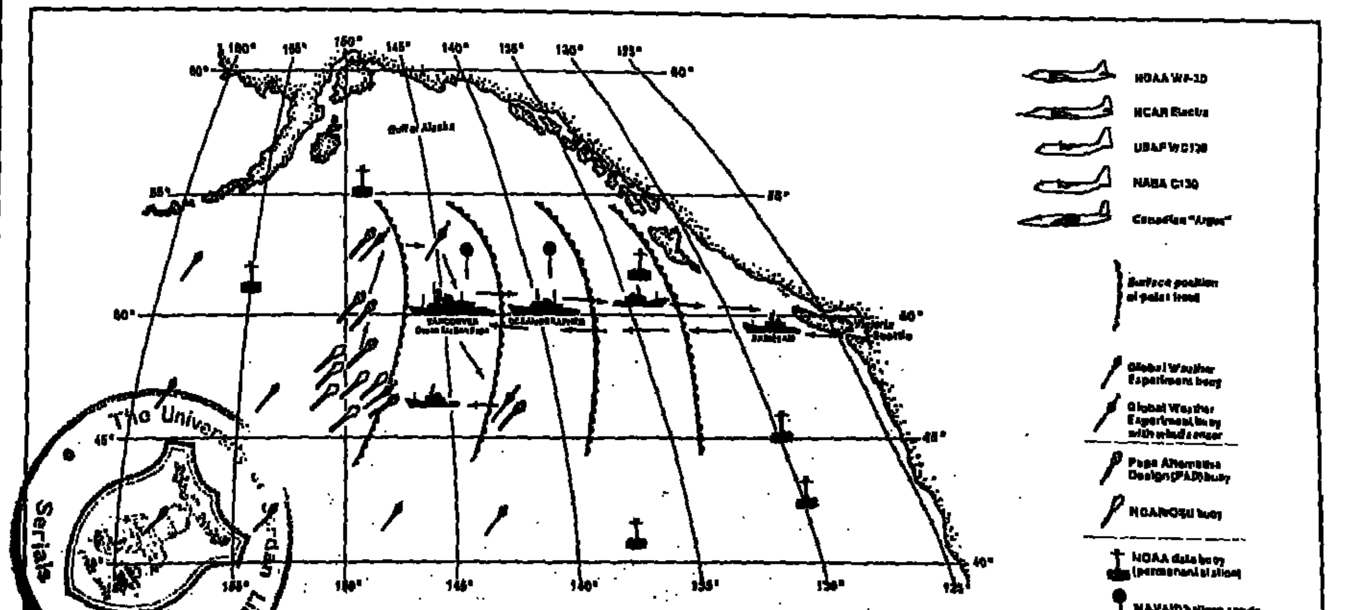
A satellite to measure the earth's radiation budget is to be integrated, tested, and delivered ready for launch on the space shuttle by April 1984. Although there have been Earth radiation budget instruments in NASA's experimental NIMBUS 6 and 7 spacecraft, this will be the first time this factor can be measured on a global basis over a 24-hour day. The earth absorbs more solar energy in some regions and emits more thermal energy in others. This heating differential sets wind and ocean currents in motion to transfer heat from heated to cooled areas. Hence, the earth's radiation budget, as a driving force for weather, is one of the factors on which comprehensive data are needed for better weather and climate predictions.

The satellite, with its Earth Radiation Budget Experiment instruments, will become part of a three-spacecraft system, with NOAA-F and -G, to use scanning and nonscanning radiometers to measure the amount of solar radiation received and given up by different regions of the earth. The satellite will include systems for power, command and data handling, attitude control (three-axis stabilized), orbit adjust, as well as a thermal control. The spacecraft will communicate via the Tracking Data and Relay Satellite System. After launch by the space shuttle, the satellite will boost itself into a 600-km (373-mile) circular orbit, inclined 46° to the equator.

The Ball Aerospace Systems Division of Ball Corp., Boulder, Colorado, will provide the Earth Radiation Budget Satellite as well as its mission operations support. The contractor's proposed estimate of this cost-plus-award fee contract is approximately $21 million.—*PMB*

Status of Voyager Spacecraft: Update

	Voyager 1	Voyager 2
Spacecraft distance from Earth, km	1,449,237,000	1,194,436,000
Spacecraft distance to Saturn, km		221,532,000
Spacecraft distance traveled since launch, km	2,264,300,000	1,964,094,000
Spacecraft velocity relative to Earth, km/s	28.6	20.5
Spacecraft velocity relative to sun, km/s	21.5	18.4



STREX—Storm Transfer and Response Experiment

STREX: Winter Storm Study in Gulf of Alaska

U.S. and Canadian investigators are probing the initial stages of the large storms that dominate North American winter weather. In a study called STREX (Storm Transfer and Response Experiment), researchers aboard ships and aircraft are examining how energy and water vapor feed from ocean to atmosphere. This action fuels the large storms that rage across the Gulf of Alaska. The low-pressure systems drift ashore in western Canada and the Pacific Northwest, break up over the Rockies, and then reform into major systems that control winter weather from Canada to Texas.

It is believed that new insights into such disturbances will improve weather predictions and lead to a better understanding of the North American climate. The experiment is man…

…spheric Environment Service. A STREX project office in Seattle will be used to coordinate the 6-week study. (Other STREX participants include the National Science Foundation, National Center for Atmospheric Research, National Aeronautics and Space Administration, U.S. Air Force, Office of Naval Research, U.S. and Canadian Coast Guards, Canada's Institute for Ocean Sciences, and Oregon State University.)

During the experiment, research ships, aided by buoys deployed in the path of the storm, will take measurements from below the sea surface to thousands of feet in the air. Also, research airplanes will probe the advancing storm fronts. As many as 10 storms should cross the Gulf of Alaska during the experiment, which ends in mid-December.

STREX goals include improved weather forecasts and …

(News cont. from page 1)

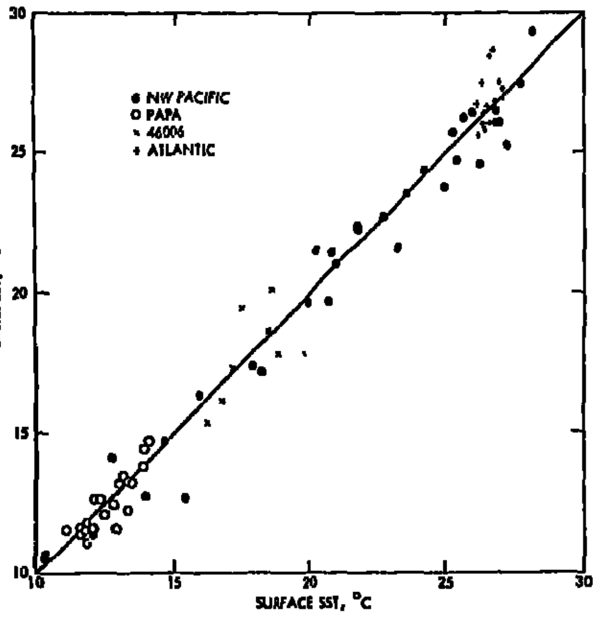
Sea Surface Temperature Measurements from SEASAT

In its short lifetime, the SEASAT Scanning Multichannel Microwave Radiometer (SMMR) observed the world's oceans for almost 100 days in the summer of 1978. This was done in order to determine sea surface temperature (SST), wind speed at the ocean's surface, rain rate, and the integrated column density of water vapor and liquid water in the atmosphere. These parameters are deduced from measurements of both horizontal and vertical polarizations of radiation at five microwave frequencies from 6.6 to 37 GHz.

SEASAT was a 'proof of concept' satellite to determine how accurately microwave sensors could measure important parameters of the oceans. The SST measurements examined so far are encouraging. They have been compared to nearly 100 high-quality surface observations under a variety of conditions and have been found to possess a negligible bias and to be accurate to within 1° over a wide range of values (10°–30°C).

The comparisons have been made in four major geographical areas: the northwest Pacific, the Gulf of Alaska, the tropical western Pacific, and the western Atlantic near Bermuda. The results are shown in the figure. The scatter about the perfect agreement line is 0.8°C, and an error analysis shows that most of the scatter is due to thermal noise in the measurements and not to errors in geophysical modeling.

There are several limitations that must presently be accepted in order to achieve better than 1° accuracy. The most serious one is that measurements must be restricted to the open ocean—large land masses within 600 km bias the SST retrievals. Also, radio frequency interference, sunglint, and heavy rain sometimes degrade the measurements. Fortunately, these restrictions only affect a small percentage of the entire data set. Furthermore, it may be possible to improve the algorithms so that they obtain accurate SST retrievals in spite of these restrictions. In any case, it is becoming increasingly clear that not only has SEASAT fulfilled its goal of validating the accuracy of microwave remote sensing but also that the SEASAT data set itself should prove to be a valuable resource for geophysical investigations.



Further comparisons to accurate surface observations are desired, especially in areas of the world not yet examined. Anyone with access to accurate SST observations made at least 300 km from large land masses during July–October 1978 are encouraged to communicate with Thomas J. Chester, JPL 238-420, Pasadena, California 91109.

Dr. Chester of the Jet Propulsion Laboratory is the contributor of this news item.

Radon: Clue to Earthquake Magnitude

Radon's flow within the earth's crust could offer seismologists clues about the magnitude of an impending earthquake, according to a model proposed by Robert L. Fleischer, General Electric Company physicist, at the AGU Fall Meeting last month. His work suggests that an extensive network of radon monitoring stations would be useful for early warning of potential damage areas of the pending tremors.

Small amounts of radon, a gas released by the decay of uranium, tends to move slowly within the earth's crust because rocks are relatively porous. Velocities of a few inches per hour are typical. Shifting stresses in the earth's crust that precede an earthquake can speed up or slow down radon's movements.

Earthquakes registering low on the Richter scale exert stresses on the earth's crust only strong enough to significantly affect radon flow in rocks, says Fleischer. These smaller tremors impact radon's flow over relatively short distances. Accordingly, stronger quakes have a greater impact over longer distances.

For example, Fleischer's calculations show that quakes rating 5 on the Richter scale should not influence radon more than 96 km away. A major earthquake, such as the 1979 Alaskan quake, measuring 7.7, could affect radon out to 3860 km.

The model proposed by Fleischer is based on a diffusion model and on the assumption that crustal stress increases with earthquake magnitude. He reports good correlation between the model and recorded fluctuations of radon seen in previous earthquakes. A similar model used by Soviet scientists shows similar correlations with other data.—*BTS*

New Publications

Modeling and Control of River Quality

S. Rinaldi, R. Soncini-Sessa, H. Stehfest, and H. Tamura, *McGraw-Hill Ser. in Water Resour. and Environ. Eng.*, McGraw-Hill, New York, xiv + 380 pp., 1979, $49.50.

Reviewed by Kenneth J. Lanfear

This book is a major work in the field of mathematical water quality modeling, providing an in-depth treatment of modeling and control techniques.

Chapter 1 is a meticulous and comprehensive discussion of modeling theory and terminology. Equations are expressed in a matrix notation which is employed consistently throughout the book and proves to be a powerful vehicle for presenting complicated models in an understandable manner. Chapters 2 and 3 examine water pollution processes and quality indicators and the different components of water quality models. Emphasis is on the forms of the various equations, rather than on the specific parameter values. Chapter 4 ties the earlier chapters together by looking at the construction of self-purification models, particularly the Streeter-Phelps model and its variations. Also interesting is a section on ecological models, using Michaelis-Menton relationships.

The strength of the book is clearly in its presentation of modeling theory. By using its concise matrix notation, it provides excellent explanations of how such effects as photosynthesis and distributed BOD loadings are incorporated into model equations. Some weaknesses on the practical side are evident. For example, in discussing ways to estimate the reaeration coefficient, only river depth and velocity are considered, ignoring recent formulations based upon energy dissipation.

Chapter 5, 'State and Parameter Estimation,' presents a major aspect of the book's modeling philosophy: Establish the modeling equations, then determine the parameters of these equations on the basis of observations of the system output. This is a sound technique, provided that past observations are appropriate for predicting future system performance. It also explains why the book devotes relatively little space to more conventional methods of estimating parameter values. The modeling philosophy will not apply, however, where such actions as stream channelization or drastic alterations of waste loadings cause the hydraulic or biological parameters to change.

One example in chapter 5 of a Streeter-Phelps model of the Bormida River is illustrative of the book's strength in modeling theory and weakness in practical application. In a demonstration of skillfully applied mathematics, the model equations were manipulated until a one-dimensional searching algorithm could be applied to estimate the parameters. However, no correction was made for the dissolved oxygen becoming zero (and changing the deoxygenation coefficient) in some of the calibration data sets. The resulting predictions of minimum dissolved oxygen are unimpressive, considering the abundance of calibration data. Chapter 6 presents even more advanced techniques, such as Kalman filters, suboptimal recursive filters, and recursive filters in time and space, but some of these are tested against synthetic model data, not field data.

The final five chapters cover such topics as control theory, linear and nonlinear programing, unsteady state control, water pollution control facilities, river basin management, and multiobjective programing. In each of these, the approach is to formulate the problems and to discuss briefly the available solution techniques. In this way, an extensive amount of useful material on theory is covered without excessive emphasis on details.

This book is definitely not for the casual reader. Understanding it takes time, concentration, and a reasonably solid background in mathematics. I would highly recommend it, however, to students of advanced water quality modeling and to practitioners facing difficult modeling situations that require advanced techniques.

Kenneth Lanfear is with the Research and Training Branch, Environmental Affairs Office, U.S. Geological Survey, Reston, Virginia.

Geology for Civil Engineers

A. C. McLean and C. D. Gribble, Allen and Unwin, Winchester, Mass., xviii + 310 pp., 1979, $25.00.

Reviewed by Ivan C. James II

A course in engineering geology was not offered the semester that I wanted to take it so I took the introductory geology course. I have always suspected that I had missed assimilating those magical formulas of rock mechanics, tunneling, and dewatering that the aspiring civil engineer dreams of using to speed his project through difficult terrain. McLean and Gribble have taken an alternative approach. Their book is not engineering geology nor is it just introductory geology, but they lay claim to geology for civil engineers as suggested by their choice of title. My impression is that they have written four chapters of geology followed by four chapters of engineering geology.

This is a distinctly British book with emphasis on glacial morphology, the use of terminology which may be unfamiliar to North American practitioners (e.g., greenfield sites, dumb wells, finite reserves, etc.), and the application to predominantly British field examples. References to the British Code of Practice and citations of information sources are also much more suited to the British student or practicing engineer.

On the whole, this book is readable, well presented, and appropriate for an introductory semester or quarter course in the subject. A strength of the book is the introduction of terminology in boldface type with the definition in context. This, coupled with a good index, should aid the practicing engineer faced with terms unfamiliar to his normal vocabulary. A lack of balance exists between some chapters as exemplified by the attention given to formulas in applied geophysics, McLean's specialty, and the lack of virtually any discussion of computational or analytical methods in the chapter on subsurface water. Although one example is the inattention to the units appropriate for the formula for subsidence found on page 189, mistakes appear to be few.

Ivan C. James II is the District Chief for New England, U.S. Geological Survey, Boston, Massachusetts.

Descriptive Physical Oceanography

G. L. Pickard, Pergamon, New York, ix + 233 pp., 1979, $9.95.

Reviewed by James H. Swift

This new edition of G. L. Pickard's enjoyable text, published only 4 years after its predecessor, shows continued improvement over the original edition. Not only are most topics brought up to date but also the book is slightly more comprehensive, and thus it is more nearly representative of modern deep-sea synoptic physical oceanography. The 'third (SI) Edition' is somewhat misleading, since few of the revisions are related to the minor matter of conversion to SI units.

The overall organization of the text remains the same, though the page count has grown slightly. The first four chapters introduce the author's approach to his subject, outline the general nature of the ocean basins, define the important physical properties of seawater, and describe their typical distributions (47 pages total). The heart of the book, comprising three-fourths of its pages, is found within the next three chapters.

Chapter 5, 'Water, Salt and Heat Budgets of the Oceans' (27 pages), is a fine introduction to the definitions of the various terms in the most common mass and heat budget equations. The regional variations in the individual components are not illustrated. This is unfortunate because such figures would make this a first-rate chapter. The budgets themselves (i.e., the combination of the various terms) are only briefly mentioned, and then in global form only.

Chapter 6, 'Instruments and Methods' (43 pages), is a gem. The instrumentation most common to physical oceanographic field work is nicely covered, and there is some discussion of the relative merits of the various techniques. Moreover, this has been combined with an effort to demonstrate how the interests of physical oceanographers have motivated the most common interpretative methods. The chapter is in no way a field manual, but it does give the reader a nicely balanced account of how one goes about measuring and interpreting physical oceanographic data.

Chapter 7, 'Circulation and Water Masses of the Oceans' (85 pages), although briefer than its companion chapter in Sverdrup, Johnson, and Fleming's *The Oceans*, is of course considerably more up to date. Pickard has achieved a measure of brevity by intentionally neglecting peripheral regions and by emphasizing modern research in the principal ocean basins. Although there is a wealth of reasonably accurate detail in this chapter, the interested reader will find it difficult to obtain more information because the sources are not cited.

The final two chapters and the appendix briefly outline coastal and estuarine oceanography, suggest future work, and discuss physical oceanographic units (20 pages total). An annotated list of suggested readings completes the text.

The revisions are in the same 'cut and paste' style used in the previous edition. This may reduce errors, but does not eliminate them. At least two errors were introduced with the change to SI units, and several other errors either persist from past editions or are introduced here. All errors are minor and should cause little confusion.

This text represents a comprehensive subject covered by few pages; hence certain topics are slighted. I missed the development of a historical perspective (only very briefly outlined) and the use of appropriate mathematics. While the nonmathematical approach will perhaps avoid frightening the nonphysicists, and while most of the essential mathematics is covered at an appropriate level in the companion volume (Pond and Pickard's *Introductory Dynamic Oceanography*), the book would have benefited from a discussion of the quasi-mathematical aspects of the distribution of variables.

Also, there has been no increase in the third edition in the use of figures to illustrate the text. Most sections would greatly benefit from an increased use of graphics. My strongest criticism is that the oceanographic literature is not properly cited. Thus the student who wishes to learn more about specific subjects cannot use this book as a starting point. Proper literature citations would add little length to the text, would not be confusing, and would greatly increase the usefulness and value of the text. I would cite Perry and Walker's *The Ocean-Atmosphere System* as an example of a related text which presents a better historical perspective, contains appropriate mathematical development, uses ample graphics, and provides proper literature citations, yet achieves this without becoming inaccessible to the nonmajor.

The third edition does, however, continue the evolution of Pickard's text into a much-needed niche in the oceanographic literature. The book does not accomplish everything one might hope, and in particular is weak on its own for introductory courses for physical oceanography majors, but I feel it is very nearly the best that can be done within so few pages.

The value of this book is that it provides in one brief, well-written volume the rudiments of physical oceanographic aspects of water mass analysis, along with the inferences such analysis provides of the characteristics and circulation of the oceans. This is an important subject not well discussed in most other texts in recent years. I would recommend this book to any person wishing a straightforward introduction to the subject. Graduate students from all oceanographic disciplines may well find it to be essential reading prior to general examinations.

James H. Swift is with the Marine Life Research Group, Scripps Institution of Oceanography, La Jolla, California.

Classified

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POSITIONS AVAILABLE

Intergovernmental Personnel Assignments/Office of Surface Mining. The Department of the Interior anticipates a few openings for temporary appointments of earth scientists during 1981 or 1982. The assignments would involve a detail from the scientist's present employer for one or two years. The present employer must be a State or local governmental entity (including state universities). The assignment would be with the Technical Analysis and Research Division of the Region V Office in Denver, Colorado or with one of the Western State's regulatory offices. Principal activities would involve technical and environmental reviews of detailed proposals to mine coal and reclaim disturbed lands and provision of technical assistance to coal mine operators and regulatory agency personnel.

Individuals in the following disciplines are needed:

1. Hydrology—emphasis on quantitative estimation of physical and chemical effects of mining and reclamation on the hydrologic system. Development of systems approach to estimating the cumulative hydrologic effects of site-specific and regional mining.
2. Mining Engineering—emphasis on comparison of mining techniques to recover additional coal and to reduce environmental effects, prediction of subsidence over underground mines; and estimation of achievement of approximate original contour.
3. Atmospheric Science—emphasis on predictive modeling of fugitive dust sources and transport.
4. Geological Engineering—emphasis on exploration geophysics (such as shallow seismic, resistivity, well log interpretation), soil and rock mechanics, and blasting (for mining).

The purposes of the assignments are to assist the Office of Surface Mining, and state regulatory authorities in the review of mining and reclamation plans for the extraction of coal from federal lands and in environmental assessments of such plans.

These assignments are intended to provide the scientist with experience and understanding of the Surface Mining Control and Reclamation Act and related federal and state statutes and regulations in order to improve his effectiveness upon return to his regular assignment.

Interested, qualified individuals and entities including state and local agencies and educational institutions, are encouraged to contact the Office of Surface Mining, Brooks Towers, 1020 15th Street, Denver, Colorado 80202 (Attn: John Hardaway, Technical Analysis and Research Division) with pertinent information regarding skills and interest. Indications of interest are encouraged as soon as possible. Scientists must meet conflict of interest requirements adopted by the Office of Surface Mining. The Department is an equal opportunity employer.

Research Associate Position. The Geophysics Program at the University of Washington seeks applicants for a research associate position in space physics, beginning June 1981. The position is supported by research contracts and grants. The applicant should have a Ph.D. and be experienced in X-ray and charged particle detector techniques as applied to space and auroral research, in addition to having good background in space plasma phenomena. Interested persons should send their resumés to George K. Parks, Geophysics Program AK-50, University of Washington, Seattle, WA 98195.

The University of Washington is an equal opportunity/affirmative action employer.

Institute of Space and Atmospheric Studies/University of Saskatchewan. Applications are invited for postdoctoral research positions in auroral physics and atmospheric dynamics. Term is one year renewable. Experimental ability or experience with optical or radio techniques is desirable. Work may involve rocket, balloon or observatory measurements and their interpretation. Send resume, references and research interests to: D. J. McEwen, Institute of Space and Atmospheric Studies, University of Saskatchewan, Saskatoon, Canada S7N OWO.

Yale University, Department of Geology and Geophysics. Applications are solicited for a faculty position in petrology or mineralogy to begin in the academic year 1981–1982. Areas of special interest to the department include theoretical and experimental mineralogy, petrology, and field studies.

Yale University is an equal opportunity/affirmative action employer and encourages women and members of minority groups to compete for this position.

Curriculum vitae, publications, and the names of three or more referees should be sent by January 31, 1981, to Robert B. Gordon, Chairman, Department of Geology and Geophysics, P.O. Box 6666, New Haven, CT 06511.

Associate Director/Marine Science Institute. The University of Texas at Austin seeks to fill the open position of associate director of the Marine Science Institute. The associate director is responsible for research and intellectual leadership of the Institute's Galveston Geophysics Laboratory. The position carries the line responsibility of senior administrator for the Galveston Geophysics Laboratory. Duties include research planning and management, fiscal monitoring and budgeting, personnel review and assignment, coordination of scientific programs and shop operations, administrative supervision, liaison with industrial and agency sponsors, representation and other directorship duties.

The Galveston Geophysics Laboratory maintains modern computing facilities, research laboratories, and two deep-ocean research vessels, the R/V Fred Moore and the R/V Ida Green. Research at Galveston includes programs in marine geophysics, marine geology, solid earth geophysics, earthquake and extra-terrestrial seismology, and instrument systems design, both basic and applied.

Applicants are asked to send the following:

(1) Vita—including list of publications.
(2) Brief statement on current research and support.
(3) Brief statement on administrative experience.
(4) Brief statement on teaching experience.
(5) Names of six persons who may be contacted for personal and professional recommendations.

A letter of application and the above requested information should be sent to:

Dr. J. Robert Moore, Director
Marine Science Institute
University of Texas
P.O. Box 7999, University Station
Austin, Texas 78712

Salary based on qualifications. Ph.D. required. The successful candidate will also be considered for tenure appointment in the Department of Marine Studies. Position to be filled as soon as possible. Early application advised. Position located in Galveston, Texas.

An equal opportunity/affirmative action employer.

Research Assistants/Utah State University. Exciting opportunities at the frontiers of knowledge exist for graduate and undergraduate research assistants in the Department of Electrical Engineering at Utah State University. USU, located at the base of the Wasatch Mountains, is engaged in ground-breaking investigations in many critical fields. Get involved in environmental sensing, digital electronics, microprocessor applications, electro-optics, or computer engineering. Do space and atmospheric physics with state-of-the-art instrumentation on the ground, in rockets, or aboard the space shuttle. For details on these and other projects, contact Doran J. Baker, Head, Department of Electrical Engineering, UMC 41E, Utah State University, Logan, UT 84332 (telephone: 801/750-2840). USU provides opportunities based only upon performance.

University of Hawaii. The Department of Geology and Geophysics of the University of Hawaii is seeking applicants for a tenure track position, beginning July 1, 1981, in either of the following fields: (1) tectonics of ocean basins and margins, (2) paleoceanography.

Applicants should have a Ph.D. degree and a demonstrated ability to conduct and promote marine research. Ability to teach at all levels is required. The position will be a joint one on an 11-month basis with the Hawaii Institute of Geophysics. The appointment will be at the rank of assistant professor. Apply with resume and names of three references to Seymour O. Schlanger, Chairman, Department of Geology and Geophysics, University of Hawaii, Honolulu, HI 96822. Closing date is April 15, 1981.

The University of Hawaii is an affirmative action/equal opportunity employer.

RESEARCH OCEANOGRAPHER

The Radar and Optics Division of ERIM requires a Radar Oceanographer, preferably at the PhD level, to function as head of the Oceanographic Measurements and Analysis Group of the EM Measurements Department. Experience as an Oceanographer including EM measurements of oceanographic phenomena is required. Experience in the management of research programs is desirable. Candidates should have knowledge of EM remote sensor systems and techniques. The EM Measurements Department conducts research programs to apply EM measurements techniques to oceanographic problems.

ERIM, a non-profit corporation, is a center of research and development on sophisticated sensors and data processing techniques used by the Department of Defense and other agencies engaged in remote sensing.

ERIM is located adjacent to the campus of The University of Michigan in Ann Arbor. The Ann Arbor area has exceptional academic, cultural, entertainment and recreational opportunities.

Send your resumé and salary requirements in confidence to John J. Malik. U.S. citizenship is required.

ERIM
P.O. Box 8618
Ann Arbor, Michigan 48107
An equal opportunity employer.

Sedimentary Petrologist. The Geology Department at the University of Vermont is seeking a sedimentary petrologist for a tenure track position at the assistant professor level. Research and teaching specializations should be in classic sedimentary petrology with potential ancillary interests in petroleum geology, geomorphology, and hydrology. It is expected that the successful candidate will establish a field-oriented research program which includes supervision of graduate (M.S.) and undergraduate students. A Ph.D. is required and teaching experience is highly desirable. The Geology Department at the University of Vermont is a seven member department having an M.S. program and a definite commitment to excellence in undergraduate education. Applications will be accepted until April 1, 1981.

Candidates should send a resume and arrange for three letters of reference to be sent to
John C. Drake
Acting Chairman
Department of Geology
University of Vermont
Burlington, Vermont 05405

The University of Vermont is an equal opportunity-affirmative action employer.

Yale University, Department of Geology and Geophysics. Applications are solicited for a faculty position in solid earth geophysics to begin in the academic year 1981–1982. Areas of interest to the department include seismology, exploration geophysics, mechanical and physical properties of rocks and minerals, geomagnetism, and tectonophysics.

Yale University is an equal opportunity/affirmative action employer and encourages women and members of minority groups to compete for this position.

Curriculum vitae, publications, and the names of three or more referees should be sent by January 31, 1981, to Robert B. Gordon, Chairman, Department of Geology and Geophysics, P.O. Box 6666, New Haven, CT 06511.

Sedimentary or Low Temperature Geochemist. This is an assistant professor, tenure track position, although exceptional candidates of higher rank will be considered. We are looking for a geochemist to complement our strong programs in sedimentology, hydrogeology, organic geochemistry, and basin analysis. The teaching load is three courses per year—one beginning level geology course, an upper level geochemistry course, and a graduate course of his/her choosing. Introductory geology and summer field camp are also taught on a long-term rotating basis. A well-equipped laboratory and computer facilities are available. The potential exists both for outside funding and for cooperative research.

The successful candidate will be expected to conduct an active research program leading to publications. Applicants should submit a letter of application, resume, a copy of each transcript, and have three supporting letters sent to:
Chairman
Department of Geology
University of Missouri
Columbia, Missouri 65211

The University of Missouri is an equal employment opportunity employer.

Postdoctoral Fellows/Department of Terrestrial Magnetism, Carnegie Institution of Washington. Endowed postdoctoral fellowships in private institution, emphasizing maximum freedom of research in areas of geophysics, isotope and trace element geochemistry, mass spectrometry, planetology, and star and planet formation. Renewable for second year. Women and minority candidates encouraged. Completed applications due March 1, 1981. For information write Fellowship Committee, Dept. of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, N.W., Washington, D.C. 20015.

Associate Program Director/NSF. The National Science Foundation's Division of Earth Sciences is seeking qualified applicants for associate program director, Geophysics Program. This position is excepted from the competitive civil service, EC-13/14 (equivalent to GS-13/14, $32,048–$49,229 per annum), and will be filled on permanent or 2-year-rotational basis. A Ph.D. in geophysics is desirable. Equivalent research and experience in the administration of large, multidisciplinary research programs may be substituted for a degree. A broad general knowledge of geologic research and familiarity with the U.S. scientific community are also required. Applicants should submit a statement of interest and resume or SF-171, Personal Qualifications Statement to the National Science Foundation, Personnel Administration Branch, Announcement Number EX 80-21, Rm. 212, 1800 G St., N.W. Washington, DC 20550. Attn. E. Paul Broglio (telephone: 202/357-7841).

NSF is an equal opportunity employer.

Graduate Assistantships/Physics and Astronomy. Graduate research assistantships and teaching assistantships in the Department of Physics and Astronomy of the University of Iowa are available to well-qualified students. The department has vigorous research programs in space physics, plasma physics, acoustics, astronomy, astrophysics, atomic physics, elementary particle physics, laser physics, nuclear physics, and solid state physics. Assistantships can begin in June, August, or January. Please address your inquiry to Department of Physics and Astronomy, The University of Iowa, Iowa City, IA 52242.

Sedimentary Geochemist. Princeton University seeks applicants for an assistant professorship within the general fields of the chemistry of sedimentary systems or the genesis/diagenesis of sedimentary rocks. Further information may be obtained from David Crerar, 609-452-4123.

Submit applications, including vita, statement of research and teaching interests, and names of three references to:
Sheldon Judson, Chairman
Department of Geological and Geophysical Sciences
Princeton University
Princeton, NJ 08544

Princeton University is an equal opportunity/affirmative action employer.

Chairperson. The Geoscience Department, New Mexico Institute of Mining and Technology, is seeking a geoscientist of recognized academic and scientific achievement for the position of chairperson. The Geoscience Department currently has degree programs through the Ph.D. in the fields of geochemistry, geology, geophysics and hydrology. Duties are to administer the department, conduct research, direct graduate students and instruct in areas of interest. Ph.D. required, salary and rank open. Letter of application, resume and letters of three references should be postmarked prior to January 25, 1981 and sent to John R. MacMillan, Chairman of Search Committee, Geoscience Department, New Mexico Tech, Socorro, NM 87801.

AA/EOE.

Assistant Professorship/Department of Physics, University of Minnesota. We expect to fill a tenure track position at the assistant professor level during the next two years. Priority will be given to candidates in space physics. Applicants will be judged in terms of their promise for outstanding scholarship in their research areas, promise for excellence in teaching, and the relationship of their research programs to programs of the department.

Candidates should send a resume, bibliography, and statement of research interests to:
Professor Walter Weyhmann, Head
Department of Physics
University of Minnesota
116 Church Street, S.E.
Minneapolis, Minnesota 55455

The candidate should arrange to have at least three letters of recommendation sent directly to the above address. The deadline for receipt of all material is February 1, 1980.

The University of Minnesota is an equal opportunity educator and employer. The University specifically invites and encourages applications from women and minorities.

Computer Specialist/University Research Environment. The University of Rhode Island is seeking an individual to help implement a Satellite Remote Sensing Software Package on our PRIME Computer System. Applicant should be interested in working in a dynamic research environment and must be capable of managing his/her own time and of seeing a project through from start to finish. Applicant must be available immediately.

The ideal candidate will have a working knowledge of PRIME and DEC RSX 11 FORTRAN, operating system subroutines and Assembly Language, experience with satellite remote sensing systems or image processing systems and a degree in computer science or software engineering. Applicants with an appropriate subset of the above skills will be considered.

Salary range is $19,310 to $22,318. Benefits include 22 days vacation and a rural oceanside setting in which to enjoy them.

Call or send resume before January 1, 1981 to Al Cutting, Graduate School of Oceanography, Computer Center, South Ferry Rd., Narragansett, Rhode Island 02882
(401) 792-6266

An affirmative action/equal opportunity employer M/F

Faculty Positions: Astronomy/Space Physics. The Department of Astronomy of Boston University invites applications for one or two tenure track faculty positions opening September 1981. Emphasis will be placed on active research experience as well as interest in graduate and undergraduate teaching. We are considering good candidates from any field of astronomy or space physics. Applicants should send resumes and the names of three references to M. O. Papagiannis, Department of Astronomy, Boston University, Boston, MA 02215.

Boston University is an equal opportunity employer.

Postdoctoral Research Associate/Mineralogy. Applications are invited for research in high-resolution and analytical transmission electron microscopy of minerals and their analogues. Experience in crystallography, materials sciences, or electron microscopy is desirable. Send resumé (including transcripts), statement of research interests, and names of three references to P. R. Buseck, Department of Geology, Arizona State University, Tempe, AZ 85281.

Arizona State University is an EO/AA employer.

Geophysics Research Associate. Weston Observatory of Boston College seeks MS in geophysics (doctorate work desirable), familiarity with time and frequency domain analytical techniques and knowledge of FORTRAN programming. Opportunity for independent research along with assigned responsibilities relating to New England seismic network. Salary to $20,000 depending on qualifications and excellent benefits. Send letter and resume to Dianne Rogers, Associate Director of Personnel, Boston College, 140 Commonwealth Avenue, Chestnut Hill, MA 02167.

An equal opportunity/affirmative action employer

Exploration Geophysics/University of Oklahoma. As part of a 5-year plan of development and expansion, the School of Geology and Geophysics is looking for a person to form the nucleus of an exploration geophysics group. A Ph.D. in geophysics is required, and preference will be given to someone whose teaching and research interests are in the acquisition, processing, and/or interpretation of seismic data. Present equipment includes a truck-mounted 'thumper' energy source, capable of penetrating a kilometer or more of rock; a portable, 12-channel seismic recording system, gravimeters, magnetometers; an electrical resistivity unit; in-house minicomputers, and terminals to the University's IBM 370 system. A geophysical observatory supports research in solid earth geophysics, and the exploration geophysicist would work closely with the tectonics-solid earth geophysics group.

Applications are due February 15, 1981. Salary is competitive with industrial standards. Inquiries and applications should be sent to John Wickham, Director, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

The University of Oklahoma does not discriminate on the basis of race or sex and is an equal opportunity employer.

Faculty Position. The Department of Geology of the University of New Mexico seeks applicants for a position in clay mineralogy, low-temperature geochemistry, carbonate petrology, or economic geology. The appointment may be at the assistant, associate or full professor level contingent on approval of funding from the university. The individual must be strongly committed to teaching at both the undergraduate and graduate levels. In addition, he or she will be expected to develop a vigorous research program in his or her field of specialty and will be expected to supervise graduate students at the M.S. and Ph.D. levels. The closing date for application is April 15, 1981. Applicants should send a résumé, undergraduate and graduate transcripts, three letters of reference, and a brief discussion of research interests to Rodney C. Ewing, Chairman, Department of Geology, University of New Mexico, 87131.

The University of New Mexico is an equal opportunity/affirmative action employer.

Virginia Polytechnic Institute and State University. Igneous Petrology and Geochemistry/Research Associate. Origin and tectonic significance of granitic rocks. Project involves petrography, analytic chemistry, mineral chemistry, isotopic studies, and field mapping. Send résumés to:
D. R. Wones, Chairman
Department of Geological Sciences
Virginia Poly. Inst. and St. Univ.
Blacksburg, VA 24061

The University is an equal opportunity/affirmative action employer.

Program Manager/Meteorology. Oceanographic Services, Inc., is seeking qualified applicants for the position of program manager for meteorological studies. Applicants should have an M.S. or Ph.D. in meteorology or atmospheric sciences, plus experience in the field. A broad general knowledge of air pollution, and an understanding of the air pollution regulatory environment, is helpful. Interested persons should send resume, references, and salary history to R. C. Banks, Oceanographic Services, Inc., 25 Castilian Drive, Goleta, CA 93117.

Resource/General Geologist. The University of Pittsburgh at Bradford will have a tenure track opening for a resource or general geologist in September, 1981. This new position will serve an established two-year program in petroleum technology and a new, geology-based, four-year program in environmental sciences. Rank and salary are negotiable. The candidate will be expected to teach introductory air photograph interpretation and at least some of the following courses in the earth and environmental sciences program: structural geology, stratigraphy, economic geology, coal geology. In addition, the candidate will teach courses in the petroleum technology program that are compatible with his or her skills. A Ph.D. and some experience are preferred, but applicants with other qualifications will be considered. Preference will be given to those with petroleum industry experience.

Bradford is located in the Allegheny Mountains in an area rich in natural and recreational resources. Please send resume and three letters of reference to Carl Burghardt, University of Pittsburgh at Bradford, Bradford, PA 16701.

The University of Pittsburgh is an equal opportunity/affirmative action employer.

Seismologist. The State University of New York at Binghamton has a vacancy for a seismologist at the assistant professor level. Candidates with research interest in exploration geophysics or earthquake seismology and a solid theoretical background are encouraged to apply. A Ph.D. with 0 to 5 years of teaching, research, and/or industrial experience is appropriate for the position. Salary is negotiable and competitive with academic institutions. Position is available in fall 1981. Please send resumé and the names of three references to Chairman, Geophysical Search Committee, Department of Geological Sciences, State University of New York, Binghamton, NY 13901.

State University of New York at Binghamton is an affirmative action/equal opportunity employer.

Structural Geologist. The Department of Geosciences of Purdue University invites application for a tenure track faculty position in structural geology, starting in August 1981. Rank and salary will be commensurate with qualifications. A Ph.D. is required. The individual will be expected to teach undergraduate and graduate courses in structural geology and tectonics, participate in summer field courses, and pursue an active research program. Preference will be given to a candidate with an applied field orientation and a strong background in the quantitative analysis of field data. The department has active programs in petrology, geophysics, and engineering geology and has a close working relationship with the geotechnical group in civil engineering and the Laboratory for Applications of Remote Sensing. Closing date for application is April 1, 1981. Applicants should send a resume, the names, addresses, and telephone numbers of three referees, and a brief statement of research interests to R. H. McCallister, Department of Geosciences, Purdue University, West Lafayette, IN 47907.

Purdue University is an equal opportunity/affirmative action employer.

University of New Orleans/Geophysicist. Applications are invited for a permanent faculty position commencing August 1981, in exploration geophysics. The Ph.D. or equivalent experience is required.

Appointee will be expected to teach graduate and undergraduate courses in geophysics and general geology, conduct a program of research, supervise theses and oversee a program in geophysics. The position will be at the assistant professor level or higher depending on background. Applications are encouraged from individuals with industrial experience, including recent retirees.

Applicants should send a letter outlining interest in position, complete resume, and three letters of recommendation to Dr. Gordon Frey, Department of Earth Sciences, Lake Front, University of New Orleans, New Orleans, LA 70122.

UNO is an equal opportunity/affirmative action employer. Applications from minority groups are specifically invited.

Geophysicist/University of South Carolina. The University of South Carolina anticipates a new faculty appointment in geophysics for 1981, subject to adequate legislative funding. We are especially interested in individuals who have expertise in the fields of exploration geophysics, seismic interpretation, or solid earth geophysics. This would be a 9-month, tenure track position at the assistant or associate professor level, beginning August 1981. Some start-up funds are available for major equipment purchases. The individual who fills this position would join the growing geophysical component of the Geology Department, which currently emphasizes seismology, regional tectonics, and paleomagnetics, and would develop an aggressive research program in his or her specialty.

Please send vitae and names and phone numbers of three individuals we may contact for references to Willard S. Moore, Chairman, Search Committee for Geophysics, University of South Carolina, Columbia, SC 29208. Closing date for this announcement is March 15, 1981.

The University of South Carolina is an affirmative action/equal opportunity employer.

Meteorologists and Hydrologists/Saudi Arabia. The School of Renewable Natural Resources, University of Arizona, invites applicants for assignment as faculty members to the Institute of Meteorology and Arid Land Studies, King Abdulaziz University, Jeddah, Saudi Arabia. One year, renewable positions in meteorology and hydrology are available.

1. Ph.D. in meteorology with experience in undergraduate teaching and research. Curriculum includes courses in meteorological instruments and methods of observation, dynamic meteorology, synoptic meteorology, physical meteorology, and climatology.
2. M.S. in meteorology with practical experience in meteorologic operations and undergraduate teaching. Knowledge of WMO procedures.
3. Ph.D. in a hydrologic science or engineering with experience in undergraduate teaching and in research. Major emphasis will be in the areas of surface and groundwater development, water management in an arid environment and in evaluating the hydrologic effects of development.

Description: The project is funded by the Saudi Arabian government through the U.S.-Saudi Arabian Joint Commission on Economic Cooperation. Administration and logistic support is provided by the U.S. Treasury Department, while the program's implementation is by a contract with the Consortium for International Development. The goal of the project is to undertake technical cooperation to develop educational programs for meteorology, hydrology, arid land studies and environmental protection.

Salaries and allowances: Highly competitive with 25% overseas adjustment, housing, car and other allowances.

Availability: February 1, 1981, or soon thereafter for spring semester; September 20, 1981, for fall semester. Initial appointment of one year or more contingent on performance.

Closing date: January 15, 1981 for spring semester; February 15 for fall semester.

Application: The application should include the following: (a) a letter detailing principal qualifications and interests. (b) a curriculum vita. (c) name, address and telephone numbers of three references. Send to Martin M. Fogel, Director, CID/King Abdulaziz University Project, 317A Anthropology Building, University of Arizona, Tucson, AZ 85721, Telephone (602) 626-5344/2988.

EEO/AA employer.

Hydrogeologist. The State University of New York at Binghamton invites applications for a permanent position in groundwater hydrology, starting fall 1981. It is desirable that applicant have teaching and research interests in one or more of the following: groundwater hydrology, modeling, flow through porous media, and environmental hydrogeology. However, applicants with interests in other areas will be considered.

Teaching responsibilities will include both undergraduate and graduate courses. The opportunity exists to initiate courses at all levels, but development of one lower-level undergraduate course is essential. Research facilities include: electron microprobe, scanning electron microscope, X-ray diffractometers, atomic absorption and transmission spectrophotometers, and access to a large central computer as well as minicomputers in department. Appointment is planned as assistant professor, but not necessarily at beginning level. Salary is negotiable, but will be at competitive academic level.

Applicants should submit resumé and arrange for three letters of recommendation to be sent to James E. Sorauf, Chairman, Department of Geological Sciences, State University of New York at Binghamton, Binghamton, NY 13901.

State University of New York at Binghamton is an affirmative action/equal opportunity employer.

Synoptic/Dynamic Meteorology.

Description: The Geophysical Institute and Division of Geosciences, University of Alaska, invite applications from qualified scientists for a full-time (12 month) faculty position at the Assistant or Associate Professor level. The successful candidate will be expected to prepare and submit research proposals to external agencies and to work cooperatively with ongoing research programs. He/she will be also expected to teach occasional courses in synoptic/dynamic meteorology at the upper division and graduate levels.

Qualifications: Ph.D. in meteorology. Research experience in advanced analysis and diagnostic studies of global-scale meteorological processes is essential, preferably over the full height of the atmosphere (0–100 km). Preference will be given to applicants who can utilize their expertise in synoptic/dynamic meteorology to synthesize the results of various ongoing research projects in mesoscale and large-scale meteorology, cloud physics, radiation, aeronomy, and space physics into a better understanding of the large-scale meteorology of the North Pacific and polar regions. Teaching experience at the undergraduate and graduate levels is desirable.

Salary: Upward to $34,800 (Asst. Prof.) or $43,300 (Assoc. Prof.) per year, dependent upon qualifications and experience.

Applications: For further information, including recent annual research report, write to Director, Geophysical Institute, University of Alaska, Fairbanks, AK 99701. Closing date for applications is February 28, 1981.

The University of Alaska is an equal opportunity/affirmative action employer.

Hydrogeologist. Applications are invited for a research position in hydrology. M.S. in hydrology or geology required, Ph.D. preferred. A minimum of 2 years experience related to water-air heat pumps, aquifer evaluation for heat pump application, and general groundwater hydrology. Position involves evaluation of Montana's aquifers for heat pump use. Send resume, copy of college transcripts, and three references to E. C. Bingler, Deputy Director, Montana Bureau of Mines and Geology, Montana Tech, Butte, MT 59701, by February 1, 1981.

An equal opportunity/affirmative action employer.

Ocean Dynamicist. An academic position (tenure-earning track) for an ocean dynamicist is presently available in the Department of Oceanography, Naval Postgraduate School (NAVPGSCOL). Present or ultimate research interest in area of naval oceanographic concern is desirable. Such areas include: ocean circulation modeling, especially prognostication on the oceanic synoptic scale; surface and internal gravity wave dynamics; synoptic analysis of oceanic data; and acoustical oceanography. The candidate should be willing and able to teach a variety of graduate courses in physical oceanography and related topics. The NAVPGSCOL has excellent computer, data archival, library, and research vessel facilities. The Department of Oceanography has close relations with the Fleet Numerical Oceanography Center, Naval Environmental Prediction Facility, and the Naval Laboratories. The department has a faculty of fifteen and a student body of 80 to 100. The overall emphasis is ocean prediction with present faculty and student research in coastal ocean, polar ocean, and air-sea interaction processes. The academic and research programs are conducted in close collaboration with the Departments of Meteorology and Physics. Salary will be determined by qualifications of the successful candidate. By January 1 if possible, send a curriculum vitae, the names and addresses of three references, and a statement of research and instructional interests to: Faculty Search Committee, Department of Oceanography, Naval Postgraduate School, Monterey, CA 93940. Visits by top candidates will be scheduled soon after. A decision will be attempted by March 1 and the position should be occupied by about June 1, 1981.

The Naval Postgraduate School is an equal opportunity employer.

COURSES

Call for Papers.
Third International Ocean Disposal Symposium
October 12–16, 1981
Alfred C. Redfield Auditorium
Woods Hole Oceanographic Institution
Woods Hole, MA 02543

For abstract and manuscript requirements, accommodations, student travel awards, and other inquiries contact:
Dr. Iver W. Duedall, Symposium Chairman
Marine Sciences Research Center
State University of New York at Stony Brook
Stony Brook, New York 11794

Meetings

Space Science Perspectives

The National Air and Space Museum will sponsor a free symposium, entitled 'Space Science Comes of Age: Perspectives in the History of the Space Sciences,' on March 23–24, 1981. Included in the symposium will be discussions of solar astronomy from space, high-energy astronomy, lunar geology, ionospheric research, launch systems technology, and a history of LANDSAT.

For additional information, contact the National Air and Space Museum in Washington, D. C.

Ocean Energy Conference

Abstracts for papers to be considered for the 8th Ocean Energy Conference, sponsored by the Department of Energy, are due January 20. The conference, scheduled for June 7–11 in Washington, D.C., has as its theme 'Ocean Energy: Meeting the National Goals.'

Papers dealing with systems orientation, industry involvement, new concepts, development planning emphasis, and technology/cost benefit projections are particularly desired. Papers stressing new and significant advances or concepts in materials, devices, or techniques relevant to ocean energy are also welcome.

Abstracts, limited to a maximum of 400 words, should be sent to Technical Committee Chairman, 8th Ocean Energy Conference, Marine Technology Society, Suite 412, 1730 M Street, N.W., Washington, D.C. 20036.

Hellenic Arc and Trench Symposium

An international symposium on the Hellenic arc and trench will be held at the National Technical University in Athens, Greece, April 8–10, 1981. The formation and evolution of the arc and trench from land- and sea-based studies and the relation to the tectonics of adjacent areas will be the symposium's focus.

Comparisons with similar geotectonic structures, including the Tyrrhenian Sea and Pannonian Basin, will be made. Results of new oceanographic and space techniques and discussion of deep lithospheric and asthenospheric processes responsible for the dynamics of the area will be emphasized.

For additional information, contact Xavier Le Pichon, Director, Geodynamics Laboratory, Académie de Paris, Université Pierre et Marie Curie, 4 Place Jussieu, Tour 15, Premier Étage, 75230 Paris.

9th Caribbean Geological Conference

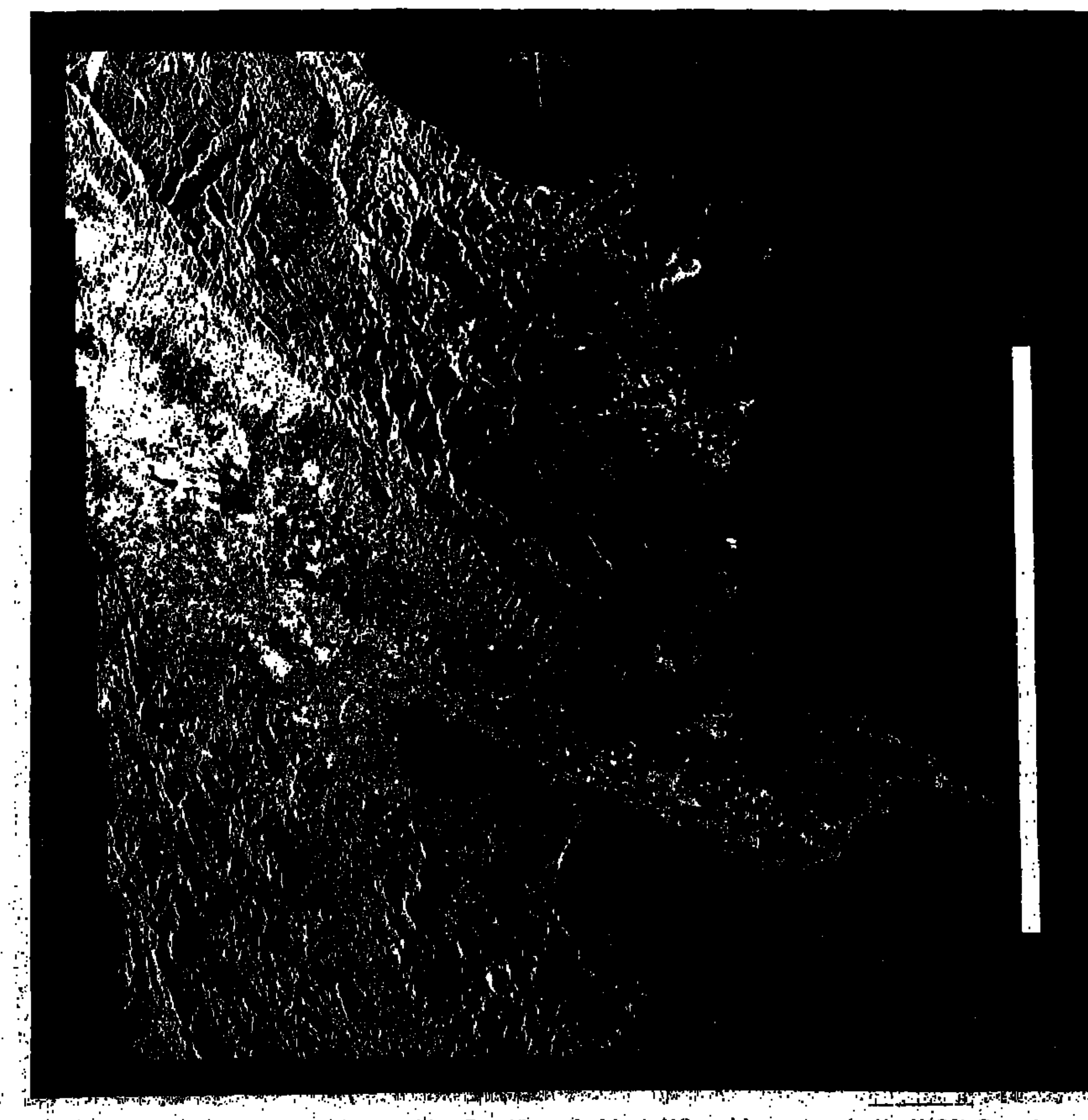
The ninth in a series of Caribbean Geological Conferences, which are held every 3 or 4 years, took place in Santo Domingo, capital of the Dominican Republic, from the 15th to 26th of August 1980. The conference, which was sponsored by the government of the Dominican Republic and the Universidad Catolica Madre y Maestra, was preceded by 2 days of field trips and was opened by President Antonio Guzman on the evening of the 17th of August. Generous support was provided by Alcoa Exploration Co., Falconbridge Dominicana, and Rosario Dominicana.

Geologists and geophysicists from 25 countries presented about 130 papers on a wide variety of topics ranging from geophysics to paleontology. While the whole Caribbean area was discussed, there was special emphasis on the northern Caribbean and Hispaniola, as befitted the site of the conference. The contribution of workers from the Dirección General de Mineriá was particularly notable.

Much of the structure, geophysics, and petrology sessions was directed toward attempting a clearer understanding of the tectonic development of the Caribbean region. Most papers concentrated on the geometrical, geophysical, and geological constraints rather than on comprehensive models. A panel discussion on the tectonics of the northern Caribbean summarized the widely differing opinions on the development of that particular region.

There seemed to be a general consensus of opinion that the neotectonics of the northern and southern boundaries of the Caribbean plate are dominated by zones of simple shear, with localized compression related to the eastward movement of the plate in relation to North and South America. New evidence from Jamaica and Hispaniola demonstrated that this is a wide zone (at least 200 km), as in the southern boundary. However, the time of initiation of this deformation is still somewhat obscure.

Other than agreement that the pre-Tertiary tectonic pattern must be constrained by the relative positions of North and South America throughout Jurassic and Cretaceous times, little consensus of opinion on the earlier development of the Caribbean was reached. There was agreement that arc systems dominated, but there was much discussion on the age, number, relative positions, and polarity of Cretaceous island arcs. Despite a wealth of structural, petrological, and geochemical data on Cretaceous igneous and metamorphic rocks, including new data from Jamaica and Hispaniola, the



This satellite radar image of the northeastern Dominican Republic, on the island of Hispaniola, was acquired by NASA's Seasat satellite, which was built and managed by the Jet Propulsion Laboratory. The image is approximately 100 km on a side, and north is toward the upper right. The line through the image center is the result of a radar calibration pulse.

Islands of the Greater Antilles group lie on the northern boundary of the Caribbean plate. Strike slip motion along this boundary is evident from major faults through the island of Hispaniola. Their trend is dominantly east-west, and in this image they strongly outline the Cibao Valley (upper left to lower right). Left lateral movement along the faults is suggested by offset drainage patterns, notably in the lower center of the image. Wave cut terraces in Pleistocene-to-recent carbonates near Cabo Frances Viejo (peninsula in the upper right) suggest that rapid uplift is also occurring along this portion of the plate boundary. (Photo supplied by T. H. Dixon, Radar Remote Sensing Team, Jet Propulsion Laboratory.)

nature of these arcs and their relation to modern arcs are still not clear. It became apparent (to this writer at least) that much could be accomplished by systematic isotopic studies on crystalline rocks to augment recent structural, stratigraphic, and petrological work.

The papers on sedimentology, stratigraphy, and paleontology were mainly concerned with Hispaniola. Recent work by two French teams, one from the Institut Francais du Petrole and the other from the Universite Pierre et Marie Curie, described thick Neogene sections in southern Hispaniola. These were interpreted as an equivalent of the underthrust sediments of the Muertos trough and as an Alpine-type flysch/molasse sequence, respectively. Stratigraphic and sedimentological investigations and tectonic implications for other parts of southern Hispaniola were also described. Stratigraphic, sedimentological, and paleontological studies of Tertiary rocks in northern Hispaniola were also discussed. This included a major presentation of results of an interdisciplinary investigation of classic Neogene sections by an international team coordinated by geologists from the Naturhistorisches Museum, Basle. Considerable controversy was generated by a new interpretation of rocks of the Scotland district, Barbados, as shallow-water deposits. Another paper pointed out that Barbados was likely to have been much farther west and nearer South America during the time the rocks of the Scotland district were deposited.

The sessions on volcanology were dominated by discussions by a University of Puerto Rico team on the character and mechanisms of pyroclastic eruptions in the Lesser Antilles. However, there were other interesting papers that dealt with the tectonic framework of the Lesser Antilles, geothermal investigations in Martinique, and the 1979 eruption of Soufriere, St. Vincent. Also of note was the description of the very recent alkalic volcanics of Hispaniola.

The economic geology section was one of the largest ever at a Caribbean conference. The enigmatic Los Ranchos Formation in the Dominican Republic, which is the host of the western hemisphere's largest and oldest gold mine, was widely discussed, as was Caribbean metallogenesis, principally in Jamaica and Venezuela. Contributors from the Dominican Republic, Jamaica, and Venezuela also presented papers on petroleum and industrial minerals.

Marine geology has always figured prominently in the Caribbean Geological Conferences, and at this meeting, highlights included French studies of the submarine geology of the Lesser Antillean Arc and Aves ridge which were complemented by a report on a deep test (Saba Bank No. 1) that bottomed in Paleocene andesite porphyry. Papers were presented on the paleomagnetism of both northern and southern margins of the Caribbean which confirmed the substantial rotations in both areas indicated by earlier studies. The general absence of magnetic anomaly signatures from the Venezuelan and Colombian basins, and the possibility that structures such as the Hess escarpments may be old fracture zones, were discussed. An assessment of the magnetic anomaly field of the Yucatan basin provides a useful basis for future research, and presentation of geoid anomalies of the Caribbean represented a contribution in a rapidly advancing field.

The conference was concluded by a stimulating (and demanding) 4-day field trip, which effectively presented a cross section of the geology of the Dominican Republic.

Further information, abstracts, and guidebooks can be obtained from 9ª Conferencia Geologia del Caribe, Apartado 2719, Santo Domingo, Dominican Republic.

This meeting report was prepared by Gren Draper, who is with the Department of Physical Sciences, Florida International University, Miami, Florida.

GAP

Geomagnetism and Paleomagnetism

1560 Time variations, paleomagnetism
MAGNETIC OVERPRINTING IN SOUTHEASTERN AUSTRALIA AND THE THERMAL HISTORY OF ITS RIFTED MARGIN
[illegible]

Hydrology

3150 Groundwater
[illegible]

3152 Groundwater
CONTAMINANT CONTAMINANT TRANSPORT WITH ADSORPTION AND ION EXCHANGE CHEMISTRY: METHOD OF CHARACTERISTICS FOR THE CASE WITHOUT DISPERSION
R.J. Charbeneau (Department of Civil Engineering, The University of Texas at Austin, Austin, Texas, 78712)
Contaminant transport in the groundwater environment with adsorption and ion exchange chemistry [illegible]

Meteorology

[illegible]

...5 µl. OH interference estimates in the case of the free troposphere were substantially lower, being 41% for an average "usable" UV laser energy of ... µl. Modeling calculations suggest that the existing $O_3/H_2O/OH$ interference problem could be reduced still further by factors of five to six, through the use of very narrow UV laser pulses (i.e., ... ns vs. ... ns).
Geophys. Res. Lett., Paper 80L1550

3720 Climatology
A CLIMATE MODEL WITH CRYODYNAMICS AND GEODYNAMICS
M. Ghil (Courant Institute of Mathematical Sciences, New York University, New York, 10012 USA) and H. Le Treut

We present a highly simplified, zero-dimensional model of the climatic system. The model attempts to incorporate mechanisms important on the time scale of glaciation cycles, namely 10^4-10^5 years. In particular, the radiation balance of the ocean-atmosphere, the plastic flow of continental ice sheets, and the viscous flow of the upper mantle are taken into account. The stress is on the interaction between the cryosphere (ice sheets) and the asthenosphere (upper mantle), which had not been taken into account in previous energy-balance or ice-sheet models of climate (Weertman, 1976; Källén et al., 1979).

The model exhibits free, self-sustained oscillations of an amplitude and period comparable to those found in the paleoclimatic record of glaciations, viz., O(10 m) and O(10^4 years), respectively. Such oscillations had already been found in the simpler model of Källén et al. (1978, 1979). The fact that nonlinear, self-sustained oscillations also obtain for the present, slightly more complex model is interesting; it offers mild support to the idea that unforced oscillations can actually exist in the real climatic system itself. These oscillations are characterized by a quarter-phase lag between ice extent and global temperature.

Given that the climatic system is a nonlinear oscillator with a period of O(10^4 years), it is expected that astronomical forcing at 19,000, 23,000 and 41,000 years will lead to subharmonic oscillations with a period close to 100,000 years, the dominant period of glaciation cycles. Such effects have already been noticed in the work of [illegible]
J. Geophys. Res., Green, Paper 80C1784

[illegible]
J. Geophys. Res., Green, Paper 80C1710

3740 Storms
[illegible]

...precipitation, which can become quite extensive in both tropical and mid-latitude systems, apparently arises as groups or successions of active convective cells leave ice particles aloft to settle downward gradually after the cells' updrafts die out.
Rad. Sci., Paper 80S1743

Mineralogy, Petrology, and Crystal Chemistry

4250 Mineral occurrences and deposits.
MARGARITE PSEUDOMORPHS AFTER KYANITE IN GLEN ESK, SCOTLAND.
Emm. Baltatzis (Institute of Mineralogy and Petrology, The National University of Athens, Panepistimiopolis, Ano Ilissia, Athens (621), Greece) and C. Katagas.

Description of a new occurrence of Margarite in a graphitic gneiss near Tettercairn village, Glen Esk, Scotland. Margarite occurs as pseudomorphs after Kyanite and contains considerable paragonite component in solid solution (~25.5 mole %). The data presented enable establishment of another tie line on the white mica plane of the system Al_2O_3-CaO-Na_2O-K_2O-SiO_2-H_2O. (Margarite, pseudomorphs, Glen Esk, Scotland).
Amer. Mineral

Particles and Fields—Interplanetary Space

5340 Shock waves
MICROINSTABILITIES UPSTREAM OF THE EARTH'S BOW SHOCK: A BRIEF REVIEW
S. Peter Gary (Physics Division, University of California, Los Alamos Scientific Laboratory, Los Alamos, NM 87545

This is a brief review of short wavelength fluctuations and their associated phenomena upstream of the earth's bow shock. Sources of free energy, the most likely instabilities and the associated nonlinear consequences which [illegible]
J. Geophys. Res., Blue, Paper 80A1676

5370 Solar wind magnetic fields
[illegible]
J. Geophys. Res., Blue, Paper 80A1638

5380 Solar wind plasma
A CAUSE OF SOLAR WIND SPEED VARIATIONS OBSERVED AT 1 A.U.
K. Hakamada (Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701) and S.-I. Akasofu

An attempt is made to interpret solar wind variations observed at the earth's distance, namely the solar cycle variations, the semi-annual variations, and the 27-day variations, as well as the polarity changes of the interplanetary magnetic field, mainly in terms of two effects, a positive latitudinal gradient of the solar wind speed and a wobbling solar dipole, combined with the annual (heliospheric) latitudinal excursion of the earth. It is shown that a significant part of the solar wind variations observed at the earth's distance and the changes of polarity pattern of the interplanetary magnetic field can be reasonably well reproduced by the two effects.
J. Geophys. Res., Blue, Paper 80A1698

Particles and Fields—Ionosphere

5500 Airglow
THE OII(7320-30Å) AIRGLOW: A MORPHOLOGICAL STUDY
J. H. Yee*(Space Physics Research Laboratory, University of Michigan, Ann Arbor, MI 48109), V. J. Abreu and P. B. Hays

A statistical study of the 7320-30Å ($O^+(^2P)$ - $O^+(^2D)$) airglow was conducted by analyzing the data taken from the Visible Airglow Experiment (VAE) on the Atmosphere Explorer (AE) satellites C and E during the time periods between 1974 and 1979. Averaged column emission rate profiles as a function of solar zenith angle and solar activity variation are presented here. The galactic background has been carefully subtracted. The result shows that the rate of decreasing emission as a function of solar zenith angle agrees with the theoretical calculation based upon a neutral atmosphere model and the solar spectrum as measured by the EUV spectrometer on the Atmosphere Explorer satellite. Furthermore, an expected increase with solar activity also appeared in a plot of emission brightness versus solar 10.7 cm flux.
J. Geophys. Res., Blue, Paper 80A1590

5515 Auroras
NUMERICAL SIMULATIONS OF ION ACOUSTIC DOUBLE LAYERS
T. Sato and H. Okuda (Plasma Physics Laboratory, Princeton University, Princeton, N.J. 08544 U.S.A.)

A comprehensive numerical study of ion acoustic double layers has been performed for both periodic and non-periodic systems by means of one-dimensional particle simulations. It is found that the number of double layers and the [illegible]
J. Geophys. Res., Blue, Paper 80A1767

5515 Auroras
POPULATION OF STABLE AURORAL RED (SAR) ARC OCCURRENCE RATES
[illegible]
Geophys. Res. Lett., Paper 80L1573

5515 Auroras
POLAR CAP F LAYER AURORAS
[illegible]
J. Geophys. Res., Blue, Paper 80A1745

5545 Ion densities and temperatures
[illegible]
J. Geophys. Res., Blue, Paper 80A1732

5560 Particle precipitation
MORNING SECTOR ION PRECIPITATION FOLLOWING SUBSTORM INJECTIONS
J.A. Sauvaud (Centre d'Etude Spatiale des Rayonnements, CNRS-Universite Paul Sabatier, 31029 Toulouse Cédex, France), J. Crasnier, ... and R.A. Kovrazhkin
[illegible]
J. Geophys. Res., Blue, Paper 80A1717

5563 Plasma motion, convection, or circulation
MODEL EXOSPHERES OF THE RINGED PLANETS
J.G. Luhmann (Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024) and ...
[illegible]
Geophys. Res. Lett., Paper 80L1385

5563 Plasma motion, convection, or circulation
POLAR CAP PLASMA FLOW ...
[illegible]
J. Geophys. Res., Blue, Paper 80A1701

Particles and Fields—Magnetosphere

5720 Interactions between solar wind and magnetosphere
THE PROPAGATION OF UPSTREAM PROTONS BETWEEN THE EARTH'S BOW SHOCK AND ISEE-3
[illegible]
J. Geophys. Res., Blue, Paper 80A1716

5736 Magnetic tail
[illegible]

5742 Magnetosheath
JUPITER'S MAGNETOPAUSE, BOW SHOCK AND 10-HOUR MODULATED MAGNETOSHEATH: VOYAGERS 1 AND 2
[illegible]
Geophys. Res. Lett., Paper 80L1385

5763 Plasmapause
HYDROMAGNETIC WAVE OBSERVATIONS IN THE VICINITY OF A MAGNETOSPHERIC PLASMA DENSITY GRADIENT
[illegible]
J. Geophys. Res., Blue, Paper 80A1639

5763 Plasmapause
PANCAKE PITCH ANGLE DISTRIBUTIONS IN WARM IONS OBSERVED WITH ISEE-1
[illegible]
... ions are reported. Pancake distributions occur often in H^+ and He^+ simultaneously while O^+ fluxes are either undetectable or field-aligned. These H^+ and He^+ pancake

distributions typically display characteristic energies of the order of 10eV and are frequently mixed with higher density, colder (kT ≲ 3eV), isotropic, quasi-Maxwellian components. They appear often within the outer regions of the plasmasphere, and seem to occur most frequently on the dayside and near the magnetic equator.
J. Geophys. Res., Blue, Paper 80A1760

5770 Short-period (less than 1 day) variations of magnetic field
ELLIPTICITY VARIATIONS IN Pi2 PULSATIONS AT LOW LATITUDES
P.R. Sutcliffe (Magnetic Observatory of the CSIR, P.O. Box 32, Hermanus 7200, South Africa)

A study of the temporal variations in the horizontal plane ellipticity of Pi2 pulsations recorded at a low latitude station reveals both nocturnal and annual variations. Ellipticity decreases from positive to negative through the night; the greatest decrease occurs during November and the smallest during May. The variations exhibit trends similar to those in plasmaspheric electron density and total ionospheric electron content. (Pi2 pulsations, polarization, ellipticity, plasmasphere).
Geophys. Res. Lett., Paper 80L1974

5770 Short-period (less than 1 day) variations of magnetic field
SPECTRAL CHARACTERISTICS OF MAGNETIC Pi2 PULSATIONS IN THE AURORAL REGION AND LOWER LATITUDES
[illegible]
... the associated auroral breakup. It becomes shorter (longer) when the auroral breakup starts at lower (higher) latitudes. The observational results substantiate well the torsional oscillation model which suggests that Pi2 is caused by the torsional hydromagnetic oscillation of the geomagnetic field line anchored on the auroral oval. (spectrum, Pi2, aurora, hydromagnetic wave)
J. Geophys. Res., Blue, Paper 80A1591

Physical Properties of Rocks

6110 Elasticity, fracture, and flow
EXPERIMENTAL HIGH TEMPERATURE AND HIGH PRESSURE FAULTS
Glenmore L. Shelton (Department of Geological Sciences, Brown University, Providence, RI 02912) Jan Tullis and Terry Tullis

Deformation experiments on Hale albite rock have produced faults at 5 to 15 kb confining pressure and 900° to 1125°C, when hydrolytic weakening is suppressed by either the absence of water or by low pressure. The faults are characterized by: 1) an angle of about 45° to σ_1, 2) very little gouge, and 3) several percent permanent strain before failure. Temperature dependent friction is believed to allow frictional sliding and faulting at stresses below those predicted by the Coulomb failure criterion, but above those of hydrolytically weakened crystal plastic flow. High confining pressure, low friction and reduced tensile stress concentrations may allow the fault to propagate as a shear rather than a tensile crack. (faults, water, high pressure).
Geophys. Res. Lett., Paper 80L1670

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Planetology

6510 Atmospheres of Planets
THERMAL STRUCTURE AND DYNAMICS OF THE JOVIAN ATMOSPHERE 1. THE GREAT RED SPOT
F. M. Flasar (NASA/Goddard Space Flight Center, Greenbelt, MD 20771) B. Conrath, J. Pirraglia, P. Clark, R. French and P. Gierasch
Temperatures and thermal winds, derived from Voyager IRIS data over the Great Red Spot and its environs, are presented. The atmosphere over the GRS is characterized by a tropopause which is cold relative to its environment and an upper stratosphere which is relatively warm. The cold tropopause implies a decrease in anticyclonic vorticity with height above 500 mb through the lower stratosphere. IRIS observations at 5μm indicate little emission from the GRS itself, but enhanced emission in a ring about it, in agreement with recent ground-based results. The behavior of the tropopause and 5μm temperatures can be consistently interpreted as resulting from a circulation which rises within the GRS and subsides in the area around it. The explanation of the upper stratospheric temperatures is not so straightforward. A previous suggestion that they may be a manifestation of the linear vertical propagation of Rossby waves appears inconsistent with the gross east-west symmetry in the stratospheric temperatures over the GRS. The implications of the present results for various theoretical models of the GRS are examined, and the possibility that latent heat release drives the GRS is discussed. Dynamical scalings based on an axisymmetric, frictionally controlled vortex suggest that, aside from the nonlinearities inherent in the parameterization of small-scale moist convection, the large-scale dynamics of the GRS are linear, as distinct from those of a tropical cyclone, which are markedly nonlinear.
J. Geophys. Res., Green, Paper 80A1783

6510 Atmospheres of Planets
THERMAL STRUCTURE AND DYNAMICS OF THE JOVIAN ATMOSPHERE II. VISIBLE CLOUD FEATURES
B. Conrath (NASA/Goddard Space Flight Center, Greenbelt, MD 20771) F. M. Flasar, J. Pirraglia, P. Gierasch and G. Hunt
Investigation of the thermal structure above selected cloud features in the Jovian atmosphere, making use of Voyager IRIS data, reveals strong similarities among a broad range of features which differ considerably in visual appearance. The atmosphere above anticyclonic features, including the major white ovals, the Great Red Spot, and a plume, are cold relative to the immediate surroundings in the upper troposphere and tropopause region. These results are consistent with upwelling and divergence in this part of the atmosphere. In contrast a "hot spot" and a "barge", which are localized cyclonic features, are found to be warm relative to their surroundings, implying subsidence with accompanying convergence. In all cases, the thermal wind shear associated with the features indicates a decay of the vorticity with height in the upper troposphere and lower stratosphere. Vertical velocities inferred from the observed temperature perturbations imply an upper limit of vertical mixing times near the tropopause of ~ 20 years. Temperatures in the upper stratosphere above the anticyclonic features show considerable variation, but in most cases are found to be relatively warm. At the present time no satisfactory explanation for this behavior appears to exist.
J. Geophys. Res., Green, Paper 80C1788

6510 Atmospheres of planets
LARGE-SCALE CURRENT SYSTEMS IN THE DAYSIDE VENUS IONOSPHERE
J.G. Luhmann (Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024 USA) R.C. Elphic and L.H. Brace
The occasional observation of large scale horizontal magnetic fields within the dayside ionosphere of Venus by the fluxgate magnetometer on the Pioneer Venus Orbiter suggests the presence of large scale current systems. Using the measured altitude profiles of the magnetic field and the electron density and temperature, together with the previously reported neutral atmosphere density and composition, it is found that the local ionosphere can be described at these times by a simple model which treats the unobserved electric field as a parameter. When the model is appropriate, the altitude profiles of the ion and electron velocities and the currents along the satellite trajectory can be inferred. These results elucidate the configurations and sources of the ionospheric current systems which produce the observed large scale magnetic fields, and in particular illustrate the effect of ion-neutral coupling in the determination of the current system at low altitudes.
J. Geophys. Res., Blue, Paper 80A1628

6510 Atmospheres of planets
OSCILLATIONS AND VELOCITY STRUCTURE OF A LONG-LIVED CYCLONIC SPOT
A. Hatzes, D. Wenkert, A. Ingersoll, E. Danielson (California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, California 91125)
Dark brown cyclonic spots ("barges") at 14° N were studied using Voyager 1 and 2 images of Jupiter. Movie sequences were made to study the spots' behavior over intervals of 30 days and longer. These movies revealed that the length and width vary by ±9% with a period of about 15 days, while the area remains approximately constant. The horizontal velocity field was investigated for an interval of about one day. Flow around the largest barge (feature 6) occurs as a ring current. The vorticity inferred is about two and one-half times that of the ambient cyclonic zonal circulation, and about one-half the value of the local planetary vorticity. Length and width variations appear to be associated with a non-zero horizontal divergence field. If the oscillations are a natural mode of the system, the 15-day period will provide an important datum for testing models of stable closed vortices. (Movie, oscillations, vorticity, divergence).
J. Geophys. Res., Green, Paper 80C1753

6540 Interior of moon (tectonics, force fields, composition, etc.)
STRUCTURE OF THE LUNAR CRUST AT HIGHLAND SITE APOLLO STATION 16
Neal R. Goins (Mobil Research and Development Corp., P.O. Box 900, Dallas, TX 75221) Anton M. Dainty and M. Nafi Toksöz
The seismic crustal structure of the moon is known in the region of Oceanus Procellarum from the analysis of artificial impact data. To extend this knowledge we have used data from natural lunar seismic events to search for secondary seismic wave arrivals in the form of peg-leg multiples caused by reflections at crustal interfaces and converted arrivals caused by refractions at crustal interfaces. A polarization filter has been applied to the data to enhance the rectilinear particle motion expected for the onset of these body wave arrivals in the scattered coda of lunar seismograms. The results of this work tentatively indicate that the highland site at station 16 has a 75 km thick crust with an intermediate 20 km interface, compared to the 60 km crust and 20 km interface in Oceanus Procellarum, a mare region. Since the 20 km upper crust appears to exist at both highland and mare sites, it probably does not represent a mare basalt layer but rather a more general feature of the crust. Crustal thickness may partially control elevation by isostasy.
Geophys. Res. Lett., Paper 80L1582

Seismology

6970 Structure of the crust and upper mantle
CONSTRAINTS ON THE SEISMIC WAVE VELOCITY STRUCTURE BENEATH THE TIBETAN PLATEAU AND THEIR TECTONIC IMPLICATIONS
W.P. Chen (Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139)
We combine observations of group and phase velocity dispersion of Rayleigh waves, of the wave form of a long period P_n phase, of P_n and S_n velocities from unreversed refraction profiles using earthquakes, and of teleseismic S-P travel time residuals to place bounds on the seismic wave velocity structure of the crust and upper mantle under Tibet. From surface wave measurements alone, the Tibetan crustal thickness can be from 55 km to 85 km, with corresponding uppermost mantle shear wave velocities of about 4.4 km/s to 4.9 km/s, respectively. The P_n and S_n velocities were determined to be 8.12±0.6 km/s and 4.6±0.1 km/s respectively using travel time data at those from earthquakes in and on the margins of Tibet. Combining results, the crustal thickness is most likely to be between 65-80 km with an average shear wave velocity in the upper crust less than 3.5 km/s. A synthesis of one P_n wave form does not provide an additional constraint on the velocity structure but is compatible with the range of models given above. In contrast to observations obtained for eight earthquakes in the Himalaya, measurements of both teleseismic P and S wave arrival times for nine earthquakes within Tibet show unusually large intervals between P and S compared with the Jeffreys-Bullen Tables. thus the P_n and S_n velocities apparently do not reflect high velocities in the mantle to a great depth beneath Tibet. From the dependence of the seismic velocities of olivine on pressure and temperature and from the similarity of the measured P_n and S_n velocities beneath Tibet and beneath shields and platforms, the temperature at the Moho beneath Tibet is compatible with being 250-300°C higher than beneath the platforms, i.e. 750°C if the temperature beneath the platforms is close to 500°C. Such a temperature could not exceed the solidus of the lower crust. Simple one-dimensional heat conduction calculations suggest that the tectonic and volcanic activity could be explained by the recovery of the geotherm maintained by a mantle heat flux of about 0.9 HFU at the base of the crust. If the distribution of radioactive heat production elements were not concentrated at the top of the crust, radioactive heating could also contribute significantly to the recovery of the geotherm and thus lower the required mantle heat flow. Thus the idea of a thickened crust in response to horizontal shortening is compatible with both these data and with these calculations.
J. Geophys. Res., Red, Paper 80B1749

Circulation in the Coastal Ocean, Part 1

G. T. Csanady

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

Introduction

Although the typical depth of oceanic basins is 5 km, a significant fraction of the earth's surface is covered by a much shallower sheet of water (only about 100 m in depth). In addition to many small lakes and lagoons, this includes extensive areas, with horizontal dimensions of 100 km and more, such as the Great Lakes, continental shelves, or large gulfs such as the Gulf of Maine or the North Sea. These relatively large bodies of water behave dynamically in an 'oceanic' manner, in the sense that motions in them are strongly affected by the earth's rotation. They will be taken to constitute the 'coastal ocean,' a term that covers enclosed and semienclosed basins, as well as open seas such as the broad and flat continental shelves of the 'Atlantic' type or the narrow and steep shelves of the 'Pacific' type.

The dominant observable motions in the coastal ocean are rotary currents, which are associated with tides over continental shelves and with inertial oscillations in stratified, enclosed seas. Such motions, in what one might call a pure form, are characterized by the rotation of the current vector through 360° in a period not very different from the earth's rotation rate, and they illustrate the dynamical importance of rotation. Water particle motions during a full tidal or inertial cycle are along a closed ellipse of a typically longer axis length of a few kilometers, there being no net displacement in an idealized pure tidal or inertial oscillation. Of course, in reality there is always some residual motion, which adds up cycle after cycle and produces fluid particle displacements over the longer term that are much larger than the diameter of the tidal or inertial ellipse. Figure 1 illustrates oscillatory and residual motion by means of a progressive vector diagram of velocities observed at a fixed point in the Great Lakes. Although this is not the same as the path of a given particle of water that passes through the instrument, over a few oscillating cycles the correspondence is close enough for illustrative purposes.

The problem of 'circulation' is to describe and understand the pattern of the residual or longer-term water particle displacements. The distribution of important water properties, e.g., temperature, salinity, and the concentration of heavy metals or nutrients, and the transport of these properties, or of life-forms incapable of locomotion, depends critically on the pattern of circulation, but not very much on the oscillatory water motions, at least not in a direct way (indirect effects include, for example, the turbulence and mixing produced by tidal currents).

This paper is the first of three parts. Parts 2 and 3 will be published in subsequent issues of Eos.

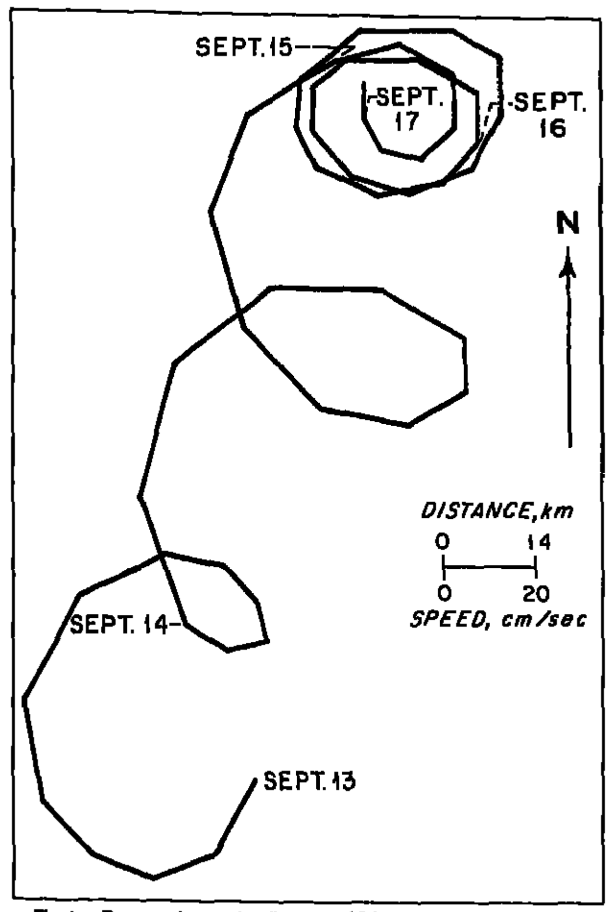

Fig. 1. Progressive vector diagram of 2-hour average currents observed at a fixed mooring in deep water in Lake Michigan. Motion consists of nearly circular inertial oscillation and northeastward residual drift. (From *Verber* [1966].)

The study of circulation and mixing processes in the coastal ocean has received considerable impetus from the recent awareness of pollution problems which have been growing since the early 1960's. In some areas of the coastal ocean, major experimental studies were undertaken which led to an impressive accumulation of observed facts and in some cases to a comparable increase in understanding. What we learned about the coastal ocean during the last 20 years certainly dwarfs previous knowledge and understanding.

It is not apparent that this greatly increased body of knowledge has so far had any significant effect on public debates of pollution problems and remedies. Perhaps those of us who have been involved in the great expansion of coastal ocean research should make greater efforts to make our voices heard. The present review is one attempt in this direction. Because our work on coastal circulation was clearly made possible by society's environmental concerns, it is appropriate to start with a discussion of this context.

The Coastal Ocean and Contemporary Civilization

Men have used the coastal ocean as a highway of commerce for millenia. The Mediterranean civilizations of the Greco-Roman world or of the Middle Ages would have been impossible without busy coastal traffic. Undoubtedly, some knowledge of coastal ocean behavior was required for safe commercial navigation. It is probably fair to say that the prosperity of many city-states on the shores of the Mediterranean, and later of the Baltic and the North seas, was built on the seafaring competence of the captains who commanded their merchant navies. Similarly, naval supremacy was critically dependent on an understanding of the sea, especially the coastal ocean. A good case can be made that the triumph of the British and Dutch naval forces over the Armada of the Duke of Medina Sidonia was not only due to superior technology but also to better acquaintance with the treacherous stretch of coastal ocean separating the British Isles from Europe.

At the present time, vessels of the limited size and endurance available to ancient mariners are still in plentiful use, although mostly for recreation. The 'search and rescue' mission of the Coast Guard protects this armada of small vessels, in support of which predictive models have been developed for the drift of disabled vessels. One of the key problems in such models is to predict surface currents in the coastal ocean accurately enough to minimize time spent in 'search' in order to proceed speedily with 'rescue.'

Another use of the sea, the roots of which are lost in antiquity, is fishing, an industry that has traditionally sustained populations of island nations such as Iceland or Japan. Today, it is well known that the coastal ocean is the main source of seafood, prime producing regions being, for example, the Grand Banks of Newfoundland or regions of 'coastal upwelling,' such as the coastal ocean off Peru. Fishing vessels are often observed to congregate near the outer boundary of the continental shelf, usually taken to be the 100 m or 200 m isobath. Why should fishing be so good at the edge of the continental shelf? The answer no doubt depends on circulation and mixing in this region, which controls the supply of nutrients to low-level life-forms. The economic importance today of the Grand Banks fishing region, and of similar highly productive regions of the coastal ocean, needs no further elaboration.

In contemporary civilization, the issue of conflicting uses of the sea has arisen with some force. One of the contentious subjects is the dumping of waste in the ocean. From one point of view, the ocean is a vast biochemical factory which can recycle a variety of wastes produced by modern man into 'nonwastes,' i.e., compounds naturally present in the environment in some concentration. When discussing the disposal of such wastes, it is natural to speak of the 'assimilative capacity' of the ocean and to exploit it when ocean disposal is more economical than other methods. Two potential problems are immediately apparent: one, wastes may have undesirable effects before assimilation, e.g. while their concentration is much above normal background concentration; two, some wastes are man-made and may not decompose into naturally present substances for very long periods, if ever. Examples of such substances that are alien to the natural environment are plutonium or PCB's, which turn out to be toxic to various life forms. On account of the toxicity of these materials, their dumping into the ocean clearly conflicts with the traditional use of the sea as a source of food.

Today, there is a bewildering variety of waste disposal or, at any rate, 'rejection' operations that have some anti-aesthetic or polluting influence on the coastal ocean. The concentrated residue of New York City's sewage (sewage sludge) has been barged to an offshore site for the past 50 years or so. This site is relatively close to the New Jersey and Long Island coastlines, where the water is only about 30 m deep. In spite of the huge volumes of sludge dumped at this shallow site over the years, adverse effects could only be documented in the immediate neighborhood of this dump site. Even here, they were surprisingly mild. Clearly, the 'assimilative capacity' for sludge of this part of the coastal ocean is impressive. Most municipal sewage, however, enters the ocean closer to shore, at the end of outfall pipes, and the local effects are not always entirely acceptable. Some industrial wastes that are otherwise difficult to dispose of are dumped at deepwater sites (106 miles from New York and off Puerto Rico, for example) that are still quite close to the coastal ocean. Electric power generation involves the rejection of large quantities of heat, released in many places into the coastal ocean. The search for and extraction of petroleum over the continental shelf leads to the release of drilling muds and to some oil spills, although the latter are dwarfed by spills from large tankers.

Conflict in the use of the sea—and of the atmosphere, lithosphere, and other parts of the hydrosphere—has brought us the regulatory agency: in the United States, the Environmental Protection Agency, the Nuclear Regulatory Commission, and other bodies with similar powers. The task of these agencies is to resolve the conflict over uses to what one would hope is the greatest good for the greatest number of people. Not even the best friends of these agencies would claim that their decisions have in fact always been this wise. One important cause of counterproductive regulation is ignorance; when the consequences of a given waste disposal operation are uncertain, there is a tendency to disallow such an operation, even when the available alternative waste disposal strategies have fairly serious adverse consequences. A case in point is the near-prohibition of warm-water discharge into the coastal ocean in such cold regions as the Great Lakes or the Gulf of Maine. Several power companies have been forced by such rules into the construction of huge cooling-tower clusters. These are unsightly, their high cost contributes to the rising price of electricity, and most importantly, they cause local climate modification of a most undesirable kind, increased incidence of fog, clouds, icing of roads, which with statistical certainty kill so many extra motorists each year. It is difficult to imagine a scenario under which the simplest straight-through discharge of cooling water directly into the coastal ocean, even without any attempt to mitigate the effects of the heated water, would have comparable consequences.

The greatest public attention has been focused on nuclear power, opposition to which has taken on religious overtones. Given the emotionalism surrounding this issue and our sensation-seeking media, this is one case where one sympathizes with the regulators in their attempts to base their decisions on reason. One alternative to a speedy development of nuclear power, including a system of breeder reactors, is continued reliance on oil imports from countries that are politically unstable. Other alternatives are no more desirable. As far as the coastal ocean is concerned, adverse effects of nuclear power are due to waste heat rejection, which takes place at a slightly higher rate than in fossil-fuel-fired plants; to the continued release of radionuclides at a low rate; and to the risk of catastrophic failure, which would be accompanied by a much greater dose of radioactive release into the coastal ocean. The extent to which these corollaries of nuclear power generation affect marine life depends on circulation and mixing in the ocean, especially in the coastal ocean where all releases are concentrated. In the case of the proposed offshore nuclear power plants, the mainland would be protected by a 4.5-km-wide moat, in which the transport and diffusion of suspended and dissolved materials would be of special interest.

Rational regulatory decisions that concern conflicting uses of the coastal ocean should be based on quantitative models

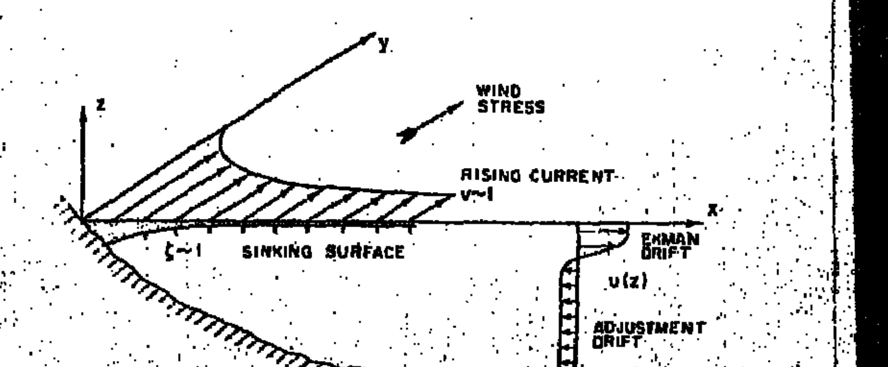

Fig. 2. Generation of coastal currents by longshore wind. Ekman drift in the surface layer onshore or offshore is compensated for by motions accompanying adjustment to geostrophic equilibrium. The fluid below the Ekman layer is accelerated in the longshore direction by the Coriolis force of (cross-shore) adjustment drift.

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Cover. Photograph shows the sawn interior of a 7.9-kg meteorite, Elephant Moraine 79001, recovered by the U.S. Antarctic expedition in 1978-79 and now part of the Antarctic meteorite collection being curated at the NASA-Johnson Space Center in Houston, Texas. The meteorite is apparently related to the shergottites, a rare group of achondrite meteorites comprising Shergotty, which fell in India in 1865; Zagami, which fell in Nigeria in 1962; and Allan Hills 77005, recovered from the Antarctic in 1977-78. The relatively young ages of these three basaltic meteorites, less than 1.4 billion years, raise interesting questions as to whether these young ages date igneous events and, if so, whether that igneous activity took place on small bodies, such as the asteroids, where plausible heat sources are a problem, or on one of the inner planets where volcanism may have persisted throughout most of solar history. Cooperative studies by several investigators will begin shortly on this new sample EETA 79001, which more closely resembles the shergottites than any other meteorite group. It is also unique among known extraterrestrial materials in showing an apparently undisturbed igneous contact between the pyroxene-rich main mass, to the left of the photograph, and the pigeonite-maskelynite basalt at the right-hand margin. Dark areas within the sample are patches and veinlets of dark glass.

that predict some agreed measure of nuisance or hazard associated with a given waste disposal or similar operation. The development of such models is a task of engineering science, which is outside the scope of the present article. These models, however, require quantitative inputs from various sciences, including the physical oceanography of the coastal ocean. In particular, a solid body of knowledge of circulation and mixing processes which is widely accepted by the scientific community is required. Otherwise, extravagant claims cannot be easily refuted, and reason becomes overshadowed by doomsday philosophy. On a rational level, the knowledge of coastal ocean physics is a prerequisite for a comparison of the consequences of oceanic disposal with the consequences of alternative disposal strategies.

Wind-Driven Transient Currents

The prime driving force of circulation in the coastal ocean is the wind. This is not always obvious in tidal waters, but people living along the shores of the Great Lakes, for example, where tides are practically nonexistent, are well aware that wind action on coastal waters rapidly generates flow predominantly parallel to the coast. The coast prevents perpendicular movement, but longshore motion is unhindered and the longshore component of the wind is particularly effective in generating longshore currents and correspondingly long particle displacements.

One of the fruits of recent field studies and associated theoretical work has been an understanding of the structure and dynamics of such wind-driven nearshore currents. Earlier ideas came mainly from pioneering theoretical studies, such as those of *Ekman* [1905], which were based on various idealizations and usually applied only to steady state frictional equilibrium flow. However, winds at mid-latitudes are variable, rarely remaining constant for more than a day. Under these circumstances the transient properties of coastal currents are often of greater practical importance than their asymptotic steady state for constant wind. These transient properties depend more on inertial forces than on frictional ones, a fact which makes the Ekman-type models of limited use.

Inertial effects may be simply understood with aid of simple models in which bottom friction is supposed absent and a longshore wind stress is suddenly imposed at the surface. Any persistent longshore motion that arises must somehow adjust to geostrophic equilibrium, i.e., the Coriolis force associated with longshore motion must eventually be balanced by an appropriate pressure field. *Rossby* [1938] first discussed such problems of 'geostrophic adjustment,' and *Charney* [1955] extended Rossby's work to coastal current generation in a two-layer ocean of constant depth. In Charney's quasi-geostrophic model, the accelerating longshore current is postulated to adjust continually to geostrophic equilibrium. In reality, this may be expected to be true for periods of order f^{-1} and longer (f = Coriolis parameter). More complete calculations for simple closed basin or coastal zone models confirm that the response of a modest size sea (f = constant) to sudden wind stress can be regarded as a superposition of a quasigeostrophic (developing) coastal current and various long waves.

The dynamical principles involved in quasigeostrophic longshore current generation that are elucidated by these theoretical studies are illustrated in Figures 2 and 3. The surface level perturbation and the longshore velocity increase hand-in-hand, maintaining geostrophic balance. In the longshore direction, the wind-stress impulse equals the depth-integrated momentum of the water column, as long as bottom friction is negligible.

The simple momentum balance in the longshore direction between the applied force and the increase of momentum in the water column can hold in the coastal zone because the depth-integrated Coriolis force associated with cross-shore flow vanishes. This is a direct consequence of the 'coastal constraint,' i.e., the condition that no water is transported in a direction perpendicular to the coast. The coastal constraint applies strictly at the coast, and to a high degree of approximation within some distance from the coast. The length of that distance is an important quantitative datum of each coastal ocean, characterizing its dynamical response and depending to a large extent on the depth distribution as a function of distance from shore. Generally, the coastal constraint holds a longer distance from shore over a flat shelf than over a steep shelf, but a number of other factors enter this question. In any event, the coastal constraint is often found to apply in water of order 100 m in depth.

In such relatively deep water, the force of the wind directly affects only a thin layer at the surface, the rest of the water column responds indirectly, through pressure forces generated by the displacement of water masses. Within the surface shear layer subject to direct wind action, turbulence governs the distribution of wind-imparted momentum, while the Coriolis force acts as an important modifier of the flow. A 'turbulent Ekman layer' develops, the depth of which depends only on wind stress and Coriolis parameter. At mid-latitudes, the typical Ekman layer depth is of the order of 10 m.

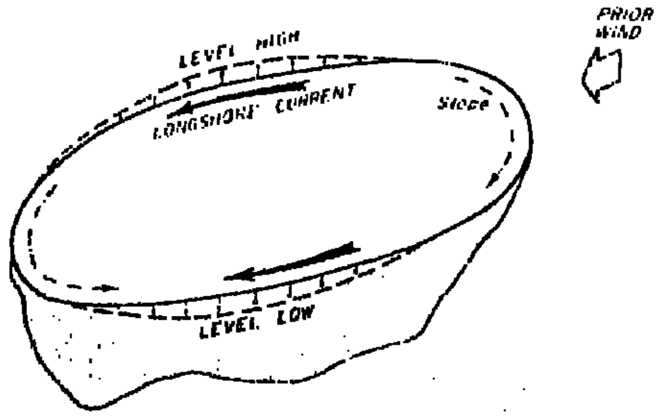

Fig. 3. System of coastal currents generated in a basin of simple shape by uniform wind. Geostrophic balance requires a rise of sea level along one coast parallel to the wind, a fall along the opposite coast.

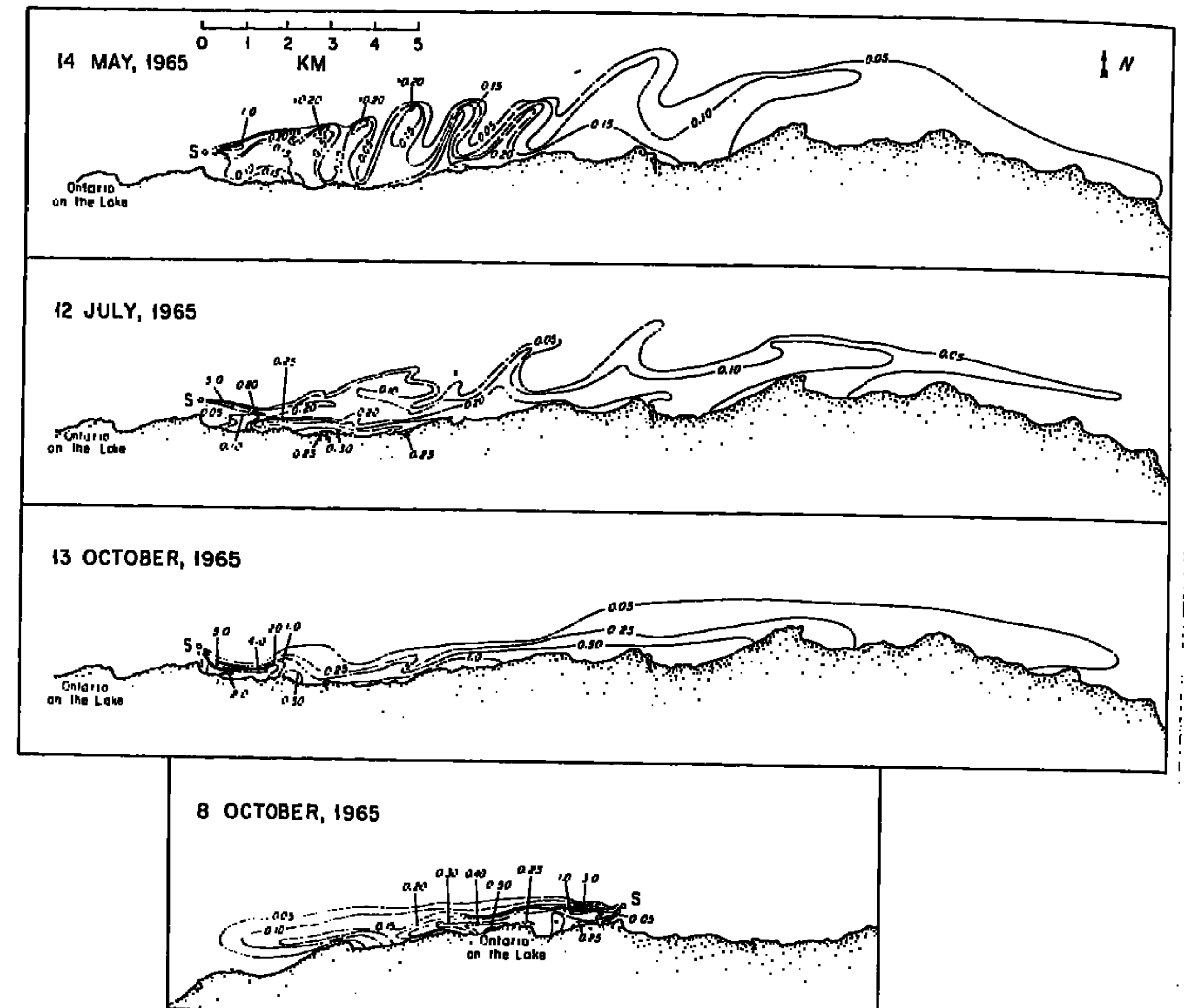

Fig. 4. Outlines of a plume generated by the continuous release of tracer dye from a nearshore source in Lake Ontario. Contours are lines of constant concentration in parts per billion (Pritchard-Carpenter, unpublished report, 1965: available from the authors, 208 Macalpine Road, Ellicott City, Md.). When the coastal current reverses direction, previously developed dye plume disappears through efficient mixing with offshore waters.

Within the Ekman layer, a longshore wind stress causes transport to the right of the wind.* To satisfy the coastal constraint, a compensating return transport occurs, evenly distributed over the water column. Where the longshore pressure gradient vanishes, this return flow gives rise to an unbalanced Coriolis force, which accelerates the water alongshore. Similar cross-stream displacements are deduced in other geostrophic adjustment problems, and the phenomenon will be referred to as 'adjustment drift.'

Sea level gradients are generally not negligible in the longshore balance of forces. For example, in a closed basin, wind 'setup' is a well-known effect. When the wind blows along the longer axis of a long and narrow basin, such as Lake Erie or Lake Ontario, the level at the downwind end of the basin rises appreciably. In typical cases in Lake Erie, the level rise is of the order of a meter, a sufficient amount to affect the output of the hydroelectric power plant on the Niagara River.

In a basin of variable depth, 'setup' balances the wind only at the locus of the cross-sectional average depth. Shoreward from this locus, in shallower water, wind stress dominates and accelerates the coastal water mass downwind. In water much shallower than the average depth, the pressure gradient force associated with setup is negligible compared to the wind force, and the previous remarks on flow without longshore gradient apply. In deep water, the pressure gradient dominates and causes return flow.

In a cross-shore transect, given a pressure gradient that opposes the wind stress, interior velocities of the developing quasi-geostrophic flow are similar to those shown in Figure 2. However, the cross-shore motion below the Ekman layer, which compensates for the Ekman drift, is now partly geostrophic flow associated with the longshore pressure gradient. Where the depth is equal to the section average depth, geostrophic cross-shore flow exactly compensates for Ekman drift. In much shallower water, the compensation (in the transient case) is mostly through adjustment drift. Longshore acceleration is only produced by the adjustment drift component.

The above theoretical framework of quasigeostrophic current generation has been amply confirmed by observations carried out in Lake Ontario during the International Field Year on the Great Lakes (IFYGL, carried out 1972–1973). At 5–10 km from shore, transient currents were found to have peak transports of a magnitude close to that expected from the wind stress impulse. The corresponding coastal-lake-level rise was documented. Although the cross-shore adjustment drift was not evident in current meter records (which were dominated by stronger signals), they could be inferred from the displacement of constant property surfaces.

Quasigeostrophic longshore currents were also found to be responsible for a rather dramatic difference in current climatology in the Great Lakes between the coastal zone (of order 10-km width) and further offshore. Nearshore, water motions are mostly straight-line and shore parallel, further away they are dominated by inertial oscillations as already illustrated in Figure 1. Lagrangian tracer studies in the coastal zone show long plumes hugging the coast in one direction or another (Figure 4). Tracer released more than 10-km offshore moves in a much more erratic manner, i.e., in essentially all directions of the wind rose.

* In the Northern Hemisphere. All other specific examples in this article refer to the Northern Hemisphere, and the effects of the Coriolis force are discussed as they apply to those cases. In the Southern Hemisphere, of course, the Coriolis force acts in the opposite direction.

Lagrangian tracer studies also show the more or less complete disappearance of a tracer plume on the reversal of the coastal current caused by an opposing wind impulse. The adjustment drift is thus seen to perform the very important practical task of renewing the coastal water mass. For a strong enough wind impulse, the renewal is more or less complete.

Similar quasigeostrophic transient currents have also been well documented over continental shelves of the Pacific type. The continental shelf off Oregon has been the subject of intensive observational studies now for almost two decades. Much of this work has been oriented toward the understanding of the seasonal upwelling cycle and its biological implications, but a considerable amount of evidence was also accumulated on the dynamics of wind-driven transient currents. Longshore wind impulses were found to be associated with longshore current fluctuations that were distributed more or less evenly over the water column (below the surface layer). The coastal sea level rose and fell in step with such fluctuations. The presence of an adjustment drift could be inferred from the movement of the constant property surfaces.

Upwelling, Downwelling, and Coastal Jets

The distribution of water properties, salinity, temperature, nitrate and phosphate concentration, etc., is particularly sensitive to the circulation in a cross-shore transect because the streamlines of such circulation often cross sharp gradients. The gradients arise on account of the stratification of the water column that characterizes the coastal ocean in the summer season. A warm (and fresh, over continental shelves) layer of some 20–30 m overlies colder and denser water, and the region separating the two layers (the seasonal pycnocline) is relatively thin, so that it may often be thought of as an interface between two fluids of slightly different density.

In a stratified water column in static equilibrium, surfaces of constant temperature and salinity are horizontal. Cross-shore particle displacements associated with transient winds distort these surfaces in a characteristic way, depending on whether the cross-shore circulation is 'upwelling' or 'downwelling.' These terms refer to the upward motion of bottom water or the downward motion of surface water, respectively.

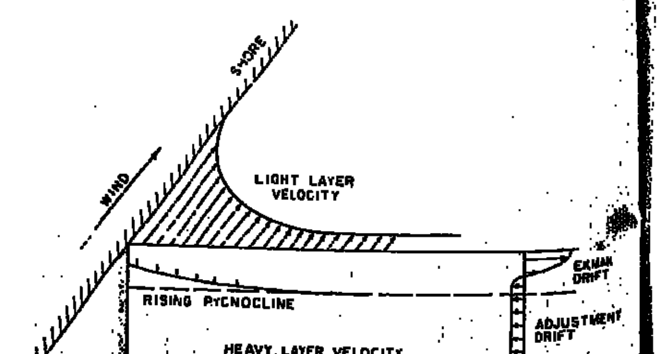

Fig. 5. Characteristics of rising coastal jet. Motion of pycnocline is only significant in a narrow coastal band (typically 5–10 km wide).

Upwelling may cause those surfaces of constant temperature and salinity, which in static equilibrium form a pycnocline or relatively sharp density interface, to intersect the free surface. Conversely, downwelling may lead to the same surfaces intersecting the bottom at a depth several times their equilibrium depth.

As surfaces of constant density depart from their horizontal equilibrium position, horizontal pressure gradients arise in the fluid and affect the adjustment process to geostrophic balance and any resulting steady state of motion. A simple and realistic theoretical model consists of two layers of constant density separated by a frictionless interface. *Charney's* [1955] analysis dealt with this model and resulted in a quasi-geostrophic solution for an infinite straight coast, constant depth, and suddenly imposed longshore wind on the assumption that the vertical excursion of the pycnocline is small ('linearized' theory). The principal difference between this and the homogeneous fluid case is that within a nearshore band only the top layer fluid responds to the wind by longshore acceleration, the bottom layer remaining quiescent. Consequently, higher longshore velocities arise in the top layer. At the same time the interface begins to rise or sink (depending on the direction of the wind) in such a way as to compensate for the surface level rise and to hold bottom pressure (nearly) constant. The strong surface layer current is then in geostrophic equilibrium with the horizontal pressure gradient associated with the inclination of the density interface and is legitimately called a coastal jet (in analogy with the atmospheric jet stream, which has a similar dynamical structure). The characteristics of a rising coastal jet are illustrated here in Figure 5.

As the coastal jet develops, the interface rises or sinks in a nearshore band of a width comparable to the 'internal radius of deformation,' which in typical coastal oceanic cases is 5–10 km. Far outside this band, the bottom layer moves bodily shoreward or seaward, while the top layer has to accommodate the Ekman drift in the opposite direction. Consideration of interior velocities then reveals a pattern exactly as if there were no density gradients, which was illustrated for a sloping beach model in Figure 2. Very close to the coast, however, there is little motion in the bottom layer. In the top layer, in the usual case when top-layer depth is about equal to Ekman-layer depth, cross-shore motions are negligible, and the force of the wind is evenly distributed over the top layer and causes uniform longshore acceleration. Where the top-layer depth is considerably greater than the Ekman-layer depth, adjustment drift occurs below the Ekman layer, but in the top layer only.

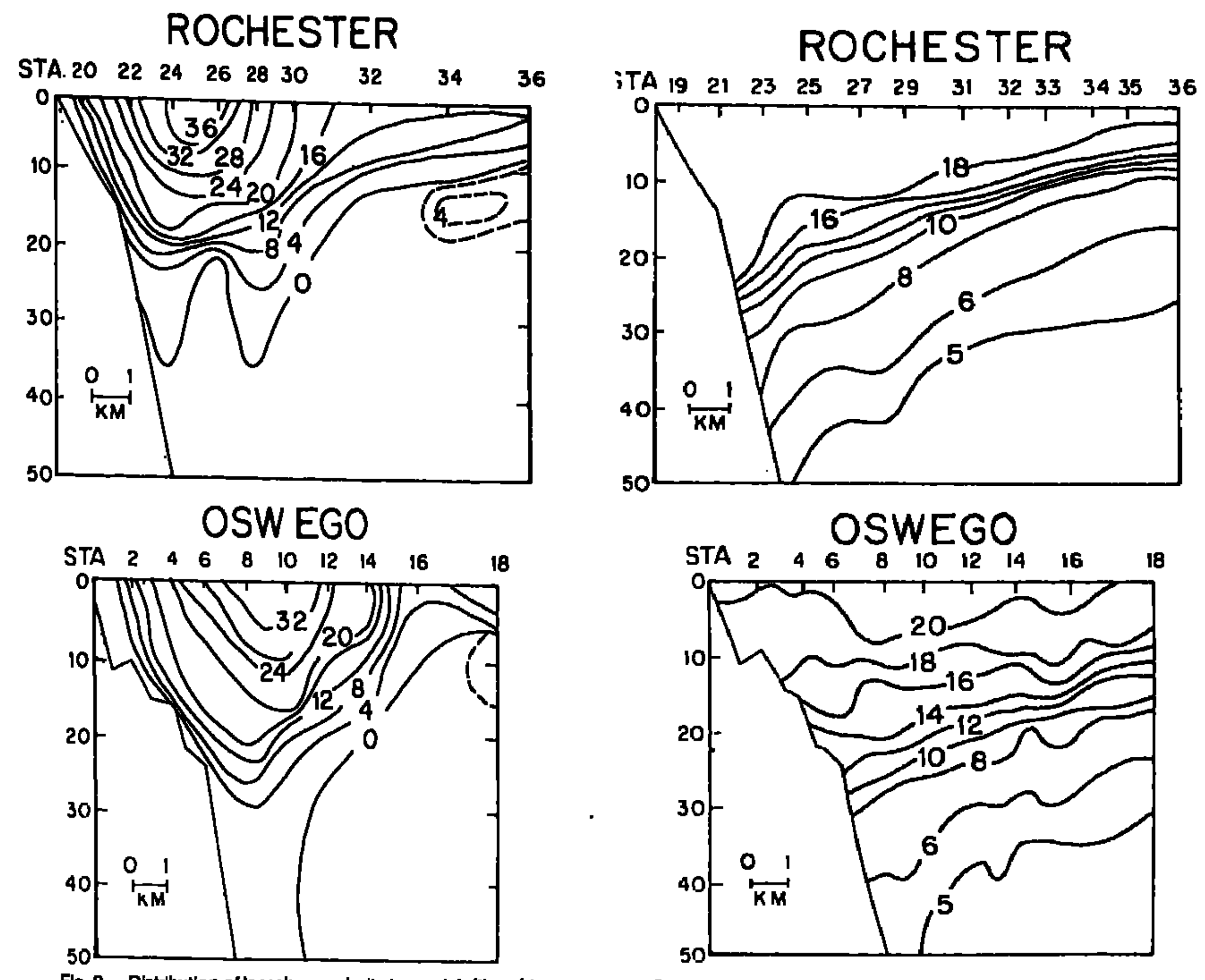

Fig. 8. Distribution of longshore velocity (cm s⁻¹, left) and temperature (°C, right) at two cross sections of the coastal region of Lake Ontario, also from IFYGL. The difference between this case and the previously illustrated one is that the velocities are here directed so as to have the coast to the right (i.e., point out of the picture), whereas in Figure 7 they point the other way, into the picture. Geostrophic balance of the coastal jet requires upwelling in the previous case, downwelling in this case. (Adapted from *Csanady and Scott* [1974].)

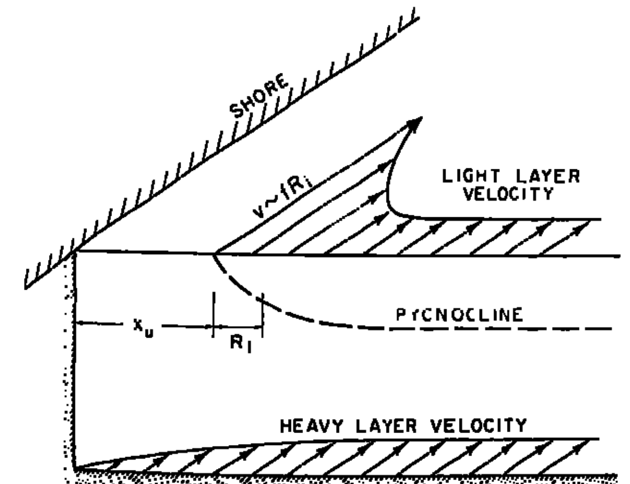

Fig. 6. Fully upwelled pycnocline following a strong enough wind impulse. Light fluid has moved bodily offshore, and the boundary between light and heavy fluid forms a surface front some distance from the coast. The coastal jet moves out from the coast with the pycnocline.

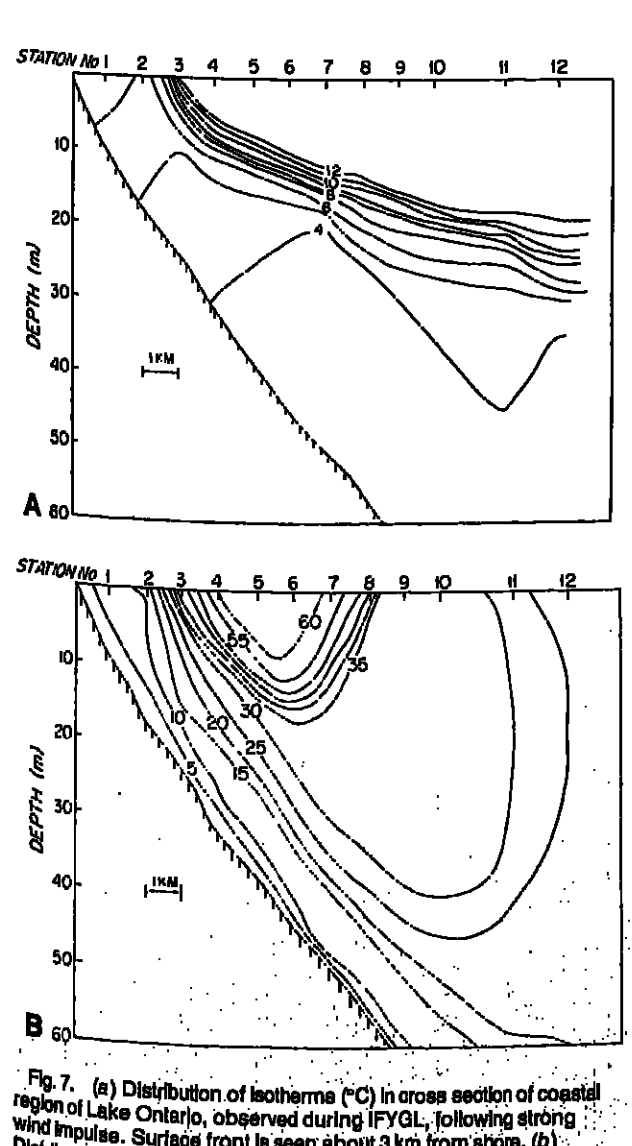

Fig. 7. (a) Distribution of isotherms (°C) in cross section of coastal region of Lake Ontario, observed during IFYGL, following strong wind impulse. Surface front is seen about 3 km from shore. (*b*) Distribution of longshore velocity (cm s^{-1}) observed on the same occasion. Core of the coastal jet lies between 4 and 7 km from shore. (From *Csanady* [1977].)

The most impressive results of upwelling and downwelling are the surfacing of isopycnals some distance from shore, or their sinking to a depth several times their equilibrium depth. The simple classical model, which postulates small vertical pycnocline excursions, does not apply to such cases. A strong longshore wind impulse is usually the cause of 'full' upwelling or downwelling events, with the large pycnocline displacements developing quite rapidly, often within hours or at most a day. It is reasonable to idealize these events by supposing that the wind impulse is evenly distributed over the top layer by vigorous turbulence. One may ask then how the two-layer fluid adjusts to geostrophic equilibrium following such an impulse, with interface and bottom friction neglected and the density of each layer separately conserved.

The extension of the classical theory on the basis of this idealization is relatively straightforward; it makes use of the principle of potential vorticity conservation [*Csanady*, 1977]. Quantitatively, the principal new result is that the velocity of the coastal jet is limited to a value about equal to the 'densimetric velocity' in the same way as maximum velocities are in certain 'critical flow' problems in hydraulics. The longshore momentum balance is completed by the Coriolis force associated with the bodily displacement (adjustment drift) of the entire top layer from shore to a distance of the order of a few kilometers (Figure 6).

It should be pointed out here than an offshore wind also causes upwelling and, if strong enough, may bring the interface to the surface. However, the flow pattern so generated is not in equilibrium without the wind acting, and the interface relaxes to a horizontal position on the cessation of the wind. Thus, in theory, the upwelling caused by a longshore wind is long-lived, an upwelling that is due to an offshore wind ephemeral. In practice, of course, dissipative processes cause the inclined interface that is in geostrophic equilibrium with a coastal jet to relax toward static equilibrium, but this is usually a slow process, with a typical time scale of 5 days or so.

Intense upwelling events are known to occur in a number of coastal locations, notably in the Great Lakes and along the Oregon coast. Early reports described the hydrography of upwelling, while later systematic studies, in the course of large-scale cooperative experiments, provided detailed information also on longshore and cross-shore currents [*Smith et al.*, 1971; *Smith*, 1974; *Mooers et al.*, 1976]. In the course of these investigations, some clearcut upwelling events have been documented. They were produced by a local alongshore wind impulse, and the observed properties of these events compared well with the above simple conceptual picture.

During the International Field Year on Lake Ontario, upwelling events in Lake Ontario could be observed with considerable spatial resolution. Figure 7 shows a well-documented event that occurred in October 1972. The wind stress impulse on this occasion was large enough to produce offshore displacement of a fully upwelled thermocline of some 3 km. The structure and intensity of the coastal jet, as well as the isotherm (= constant density surface) distribution, was very much as expected from the simple theoretical model described above.

Examples of downwelling and associated coastal jets have also been documented in the Great Lakes. An example is shown in Figure 8. This also conforms in all essential aspects to the finite displacement quasigeostrophic model.

Acknowledgments

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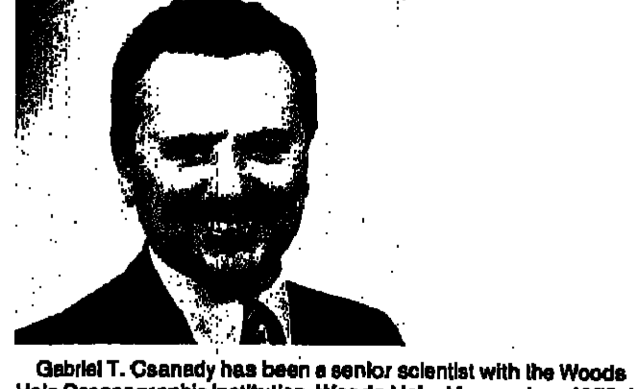

Gabriel T. Csanady has been a senior scientist with the Woods Hole Oceanographic Institution, Woods Hole, Mass., since 1973. He was educated as a mechanical engineer (Dipl. Ing., Munich) and worked 5 years in the electric power generation industry in Germany and Australia before embarking on graduate work on air pollution meteorology. He received his Ph.D. from the University of New South Wales in 1958. He joined the University of Waterloo, Ontario, in 1963, where he was professor of mechanical engineering and department chairman for a period, while also beginning a series of experimental and theoretical studies on the dynamics of coastal currents in the Great Lakes. In the late sixties these studies were carried out in cooperation with the Great Lakes Institute, University of Toronto, and were stimulated by extended visits to the Department of Meteorology, University of Wisconsin, Madison. Increasing involvement with coastal oceanography led to the move to Woods Hole, where he worked mostly on dynamical problems of continental shelf circulation, with special emphasis on the coastal boundary layer. He was editor of the green JGR for a 4-year term, ending in December 1979, and currently edits a book series on environmental fluid mechanics (Reidel Publishing Co.). He is a recipient of the President's Prize, Canadian Meteorological Society (1970), the Editors Award, American Meteorological Society (1975), and the Chandler-Misener Award of the International Association for Great Lakes Research (1977). He is author of the monograph 'Turbulent Diffusion in the Environment' (1973) and is currently working on another monograph entitled 'Circulation in the Coastal Ocean.'

News

The Love Canal: Beyond Science?

When in 1978, the New York State Department of Health issued the report, 'Love Canal—Public Health Time Bomb,' the serious effects of chemical waste contamination in the Love Canal area became an issue of national concern. A few 'studies' since then have produced results in concert with those of initial reports that described 'conditions of acute health effects' as being linked to hazardous wastes incorporated in landfill in the Love Canal site near Niagara Falls, New York. Now that a 'blue ribbon' panel of experts from the medical sciences has reviewed the problems of Love Canal, however, a different view has emerged. The 'Report of the Governors' Panel to Review Scientific Studies and the Development of Public Policy on Problems Resulting from Hazardous Wastes,' transmitted in October of this year, identifies the following factors about the health effects at Love Canal:

- inadequate research designs for health effects studies, particularly regarding chromosome damage and informal surveys of the Love Canal residents;
- the inevitable necessity of time required for longitudinal prospective studies and complex retrospective studies that concern long-term exposures to hazardous wastes.
- inadequate intergovernmental coordination and cooperation in the design and implementation of health effects studies.

It is apparent that in the 2 years following release of the original New York Department of Health report, a most difficult state of affairs developed. On one hand, there is clear evidence that contamination of the subsurface, groundwater, and household basement areas of the Love Canal residents occurred (toxic chemicals, including chlorinated hydrocarbons and dioxin, among many others). On the other hand, there were no 'short-term' health problems, according to most studies. The result was a state of understandable hysteria of the residents of Love Canal because of the danger of 'long-term' health problems such as the development of cancer, birth defects, and other conditions that might be produced by chromosomal damage. The real problem is that, according to the recent finding of the governor of New York's panel, the science is not well enough developed to understand, much less to prove, a causal relationship.

The alarm raised in 1978 was, in part, a legal requirement of state law section 1388 to 'insure adequate jurisdiction and resources for governmental response to the Love Canal situation.' To obtain support for a 'national disaster,' the New York State Department of Health had to define the disaster. Unfortunately, the state of fear and anxiety that resulted led to an unfortunate test of the scientific method. The panel report states:

> This Panel recognizes that there was a reason for the State Health Department's initial announcement of 'Public Health Time Bomb,' but not a good enough reason. There ought to be a better mechanism for convincing the Federal government that a certifiable disaster area exists, in order to obtain Federal funds, than to arouse such fears of imminent peril as swept through the Love Canal area in this case. A better mechanism might have been found if effective Federal/State consultations had been launched promptly when the problem was first recognized. It may be that the atmosphere of public near-hysteria which was created in mid-1978 contributed to the failure on the part of public health agencies to put together an appropriately orderly, deliberative and systematic investigation of the situation.
>
> This Panel acknowledges that the Love Canal problem was something quite new, a situation not encountered before by public health agencies. In the past, instances of environmental pollution emerged as sudden, acute episodes, usually derived from a single industrial source, with readily discernible and quantifiable health hazards. Love Canal, in contrast, represented the chronic contamination of a whole community's living space, extending back over a period of decades, and most complex of all, involving not one but scores of different chemicals seeping through the earth and into households all at once. No book of rules exists for handling this kind of problem, but from now on it is obvious that rules will have to be formulated.

The Environmental Protection Agency (EPA) released a study of the problem that the panel describes as 'a paradigm of administrative ineptitude.' Although the EPA qualified its findings to be used with 'prudence' because of inadequacies of the study, the findings were widely distributed, to no one's loss. According to the panel report:

> The public was given the strong impression that the Love Canal pollution was endangering the survival of all contacts and their offspring. During the next few weeks the Biogenics report (basis of the EPA findings) was reviewed by several groups of experts in the field of cytogenetics, with expressions of doubt that the reported results were of significance. These were particularly critical of the techniques employed, the lack of controls, and the possibly artifactual nature of the supernumerary acentric fragments.
>
> With so much at stake for the residents involved, to have set up experiments that lead to public conclusions of such magnitude, without prior review of the protocol by qualified uninvolved peer scientists, and without any after-the-fact, independent review of competent scientists before release of the results, was a disservice to the citizens most intimately concerned and, as well, to the public at large.
>
> It is a pity that this matter was so badly handled. There was no good reason why the responsible authorities in EPA could not have consulted beforehand with their counterparts in the New York State DOH, and enlisted the advice and close participation of outside consultants with international reputations in the field of cytogenetics, and then mapped out a thorough, careful and scientifically valid approach to the question of chromosome injury.

There is now no question that a proper cytogenetics study is urgently needed. The Panel does not know whether the degree of chromosomal injury claimed in the Biogenics Laboratory study, even if confirmed, is in itself a reason for alarmed predictions concerning cancer or congenital defects—indeed, similar chromosomal abnormalities are characteristically observed in other circumstances (measles, for example) without known sequelae. However, the mere fact that the chromosomal damage is real—if it is—means that the residents of Love Canal are being biologically affected by *something* in their environment, and this observation—if confirmed—would greatly weaken the position, taken by some, that the only ill effects suffered by this population are psychological.

There will be, no doubt, countless studies of the Love Canal incident in the future. The U.S. Public Health Service, the National Academy of Science, and the New York State Department of Health will initiate studies or maintain progress in studies now underway. Perhaps science will benefit by these studies, and, possibly the forefront of environmental/health research will be extended. Right now the important questions about cause and effect, risk assessment, and acceptable levels remain unanswered.—*PMB*

Postal Cancellation From Spaceport

The John F. Kennedy Space Center, in cooperation with the United States Postal Service, is offering a cancellation service to interested philatelists for the space flight programs at Kennedy.

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- Specify the event for which you wish this service. There is a limit of five covers per customer per event.
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- hand-back service.

Since the Kennedy Space Center post office is open only Monday through Friday, excluding legal holidays, envelopes cannot be cancelled on Saturday or Sunday. Cancellations for minor tests cannot be given because access to these schedules is not available.

Radio Astronomy in Earth Studies

A high precision radio astronomy system has been adopted and used at the Goddard Space Flight Center in studies of the movement of the earth's crust. Very Long Baseline Interferometry (VLBI) can measure the rotation of the earth, and polar motion, with a current precision of better than 10 cm. Such precise measurements may shed light on the relationship between changes in the earth's orientation and movements in the earth that are associated with large earthquakes. Such movements may occur before an earthquake, but so slowly and over so large a region as to be undetectable by conventional means. Using VLBI stations, the Crustal Dynamics Project has made measurements on the longer baselines to measure continental drift, and on the shorter ones to monitor regional activity.

The technique uses two or more antennas to observe fixed extragalactic sources, usually quasars. Applying this principle to Earth crustal studies, the quasar signal's difference in arrival times at the two stations can be used to geometrically determine the distance between the two stations with a high degree of accuracy.

The baseline, or straight-line distance, between stations at Westford, Massachusetts, and Bishop, California, has been measured with a precision of 3 cm, or better than one part in a hundred million.

Formation, with other countries, of a global station network and some of its work were reported by geophysicist Chopo Ma at the AGU Fall Meeting in San Francisco, December 10. Ma reported that a number of fundamental questions in geophysics are now being investigated by using space techniques. What is the nature and magnitude of tectonic plate motion? What is the behavior within a plate, especially continental plates such as North America? What is the relationship between fluctuations in the earth's rotation and large earthquakes?

The VLBI method is now using a highly sensitive, accurately calibrated, automated system (Mark III) which is designed for making geodetic measurements with fixed or mobile radio astronomy antennas of various sizes, ranging from 4 to 64 m in diameter. The project has conducted geodetic observations with the Mark III systems at fixed radio astronomy stations in California and Massachusetts, mentioned earlier, and at Green Bank, West Virginia; Ft. Davis, Texas; Onsala, Sweden; Bonn, W. Germany; and Chilbolton, England. The Crustal Dynamics Project group at the Jet Propulsion Laboratory is implementing the Mark III system into a mobile station for measurements of crustal movements in the western United States.

Since 1976, measurements from Massachusetts to West Virginia and California indicate overall continental stability, i.e., no more change than 2 cm/year. The baselines to Texas, first measured in April 1980, will allow more detailed examination of the eastern and western sections of North America. Many measurements have been made in California since that is an area of known regional activity.

In cooperation with the National Geodetic Survey and several international organizations, VLBI measurements were made by NASA in July, September, and October 1980, as part of the Monitoring Earth Rotation and Intercomparison of Techniques Program. These data, equal in amount to what was acquired in two previous years, are now being analyzed and are to be published next spring. They will provide unprecedented opportunities to compare the details of the earth's orientation as determined by other techniques and to check the United States-to-Europe baselines for plate motion and stability.—*PMB*

New Marine Studies Center

Temple University has established a Center for Marine Studies with faculty members from four of its colleges. The center will offer courses leading to a certificate in marine studies.

Studies will focus on urbanization's impact on the marine environment and will focus on management and economics of waterfront utilization. In addition, faculty members will be constructing an artificial reef off Absecon Inlet to determine if increasing protective environments will permit increased sport fishing.

Course offerings will range from oceanography and marine biology to scuba diving and underwater research and data collection.

For additional information about the center, contact Robert Leahy, Director, Center for Marine Studies, Temple University, 209 Beury Hall, Philadelphia, Pennsylvania 19122 (call 215-787-8720).

Weather Predictions on Target

The western third of the United States will be warmer and dryer than normal this winter, according to Jerome Namias, a meteorologist at the Scripps Institution of Oceanography's Climate Research Group. However, the East coast will be colder and wetter than normal, he predicted. These predictions, made early in December, have proven correct through the beginning of January.

'Indications point to colder than normal temperatures over the eastern half of the nation and also over the Southwest from New Mexico through Oklahoma and Texas, and warmer than normal temperatures over the western third of the nation,' said Namias, a principal investigator for Scripps' North Pacific Experiment (Norpax). Florida will probably experience near-normal temperatures.

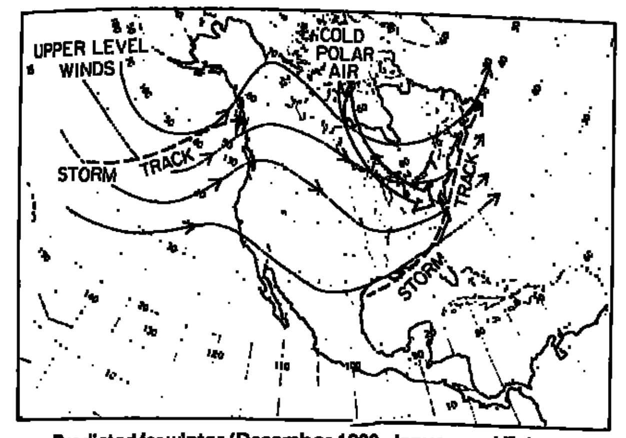
A major change from last winter's weather, the predicted pattern is the result of a trough in the prevailing winds between 3,000 and 12,200 m. Last winter's weather was mild from the Great Plains eastward to New England, dry and relatively snowless over much of the East, but abnormally wet over the Southwest, particularly in California.

This winter, the prevailing-wind trough is expected to extend from New England southwestward to Texas, where a strong ridge is expected over the Canadian Rockies and along the West coast. This wind pattern would encourage movement of cold polar air masses into the East but would shield the West, Namias explained. This pattern also favors more frequent storms along the Gulf Coast and the Atlantic seaboard.

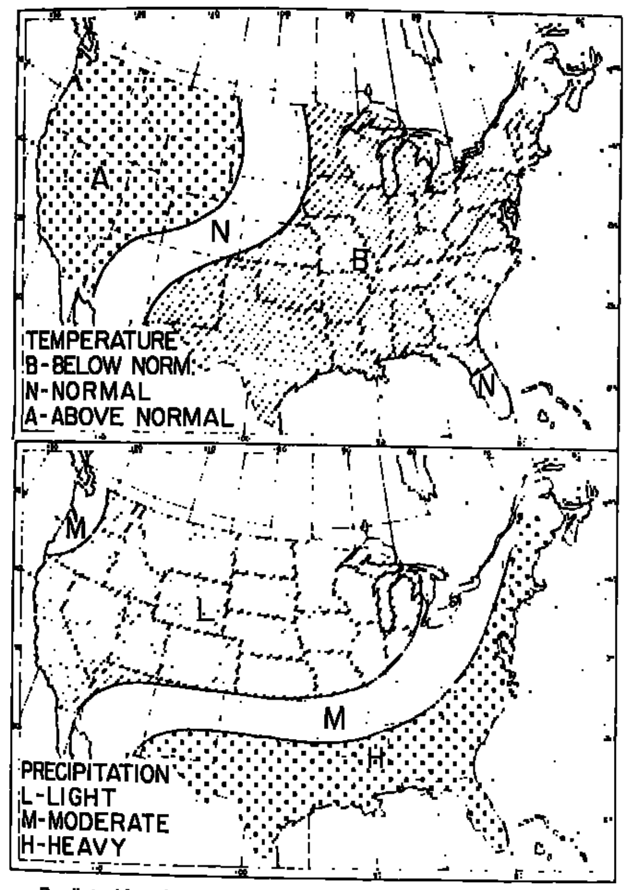
In the East, some of the snows, once generated, would influence the atmosphere that would further refrigerate the air, he said. 'By increasing the temperature contrast between the continent and the Gulf Stream, development of East coast storms would be enhanced,' Namias adds.

The Dakotas, Nebraska, and parts of Colorado, New Mexico, and Arizona, which lie in a region between the above and near-normal temperature zones, will experience large weekly temperature fluctuations that will average out to near-normal temperatures for the season.

Namias' weather-prediction techniques utilized, in part, data on ocean-water temperatures as indicators for changes in climate over the continents.



Predicted for winter (December 1980, January and February 1981). Source: Scripps Institution of Oceanography.



Predicted for winter (December 1980, January and February 1981). Source: Scripps Institution of Oceanography.

Federal Coal Directory

A new catalog that provides the addresses and the telephone numbers of more than 400 national and local coal-related offices of the U.S. Geological Survey, Office of Surface Mining, and the Bureau of Land Management is available from the USGS.

The 41-page publication, a cooperative effort of the three Department of the Interior agencies, contains a statement of each of the bureaus' functions and activities and a listing by state of selected headquarters offices and field offices.

Single copies of the new publication, 'Catalog of Selected Offices of the Office of Surface Mining, Bureau of Land Management, and the Geological Survey Relating to Coal, 1981' (USGS Circular 840), may be obtained free of charge from the USGS Branch of Distribution, 604 South Pickett Street, Arlington, Virginia 22304.

Atmospheric Sciences Assistantships

Research assistantships for graduate students in the atmospheric sciences are available from the National Center for Atmospheric Research (NCAR). Research topics should cover atmospheric dynamics, climatology, cloud physics, atmospheric chemistry and radiation, upper atmosphere physics, solar and space physics, oceanography, or environmental and societal impact assessment.

Appointments are half-time and offer salaries of $6085 for students who have passed comprehensive examinations and $7520 for those who have not. Maximum tenure for Ph.D. candidates is usually two years, but M.S. candidates are usually restricted to 1 year. In unusual cases, an additional year may be possible.

Additional information may be obtained from Betty Wilson, Administrator, Advanced Study Program, NCAR, P.O. Box 3000, Boulder, Colorado 80307.

Geophysicists

Neil H. Berg is now in charge of snowpack research for the Forest Service's Pacific Southwest Forest and Range Experiment Station in Berkeley, California. In his new position, he will direct a team of scientists to study forest management in the snow zones of the Sierra Nevada and Coast Ranges in California.

Paulikas

George A. Paulikas has earned a Trustee's Distinguished Achievement Award for 'outstanding international leadership in magnetosphere physics and its applications to military space systems' at The Aerospace Corporation. The award consists of a bronze plaque and $10,000 cash.

Paulikas, associate editor of the *Journal of Geophysical Research*, 1972-1974, has been director of Aerospace's Space Sciences Laboratory since 1968.

Spilhaus

Athelstan Spilhaus will be a Distinguished Scholar at the Center for the American Experience, Annenberg School of Communications, and a research fellow in the Institute for Marine and Coastal Studies, University of Southern California, Los Angeles, from January through June 1981.

Herbert W. Stoughton joined the geodetic survey squadron of the Defense Mapping Agency at the F. E. Warren Air Force Base in Wyoming.

Robert L. Wesson has been officially appointed assistant director for research at the U.S. Geological Survey in Reston, Virginia. He succeeds *James R. Balsley*, who retired a year ago. Wesson has contributed to earthquake research aimed at prediction and mitigation of quake hazards.

Geophysical Events

This item comprises a selected portion of *SEAN Bulletin*, *5* (11), November 30, 1980, a publication of the Smithsonian Institution.

Volcanic Activity

Mount St. Helens Volcano, Cascade Range, southern Washington, U.S.A. (46.20°N, 122.18°W). All times are local (GMT − 8 h). After the explosions of October 16–18 and the brief period of lava dome growth that followed, activity at Mount St. Helens was limited to vapor emission and occasional seismic activity through early December.

Most early November seismic events were caused by rock slides from the crater walls. No significant local earthquakes or harmonic tremor were recorded until mid-November, when brief episodes of harmonic tremor began, barely within the detection limits of sensitive seismographs on and near the volcano. Intermittent low-level tremor continued through early December. Stronger tremor started on November 25 at 2054, gradually fading into background noise about 35 min later. Observers in a U.S. Forest Service aircraft reported a slightly brighter glow in the dome area after this event. A second burst of stronger tremor began November 27 at 2034, continuing for about an hour, and several more such episodes, lasting only a few minutes each, were detected through November 30.

U.S. Geological Survey monitoring of the north crater rampart revealed a maximum net outward movement of about 23 cm between the October explosions and November 26. However, a major reversal to inward movement occurred in late October before an outward trend resumed in November. Outward growth accelerated in mid-November to slightly more than 1.5 cm/day at times, a rate similar to that recorded during the summer. About 20 cm of expansion was measured between November 12 and 26.

No major changes have taken place in the volume or ratio of gasses emitted by the mountain. Two large fumaroles opened in the crater floor, very close to the margin of the lava dome, one on November 18 or 19, the other on November 25. As they opened, both ejected mud (containing no fresh magma) that coated snow on the flank. As of early December, the new fumaroles were 2–3 m across, glowed cherry red, and puffed noisily at half-second intervals.

The following is a report from W. G. Melson.

> A small but definite trend toward andesite compositions is revealed by major element analyses of the 18 May to 7 August eruptives. A total of 46 samples of probable essential ejecta have been analyzed (Table 1 and Figures 1*a* and 1*b*) a minimum of five such samples from each eruptive episode. The trend is an irregular one and is more pronounced with regard to MgO and CaO when plotted against time of eruption.

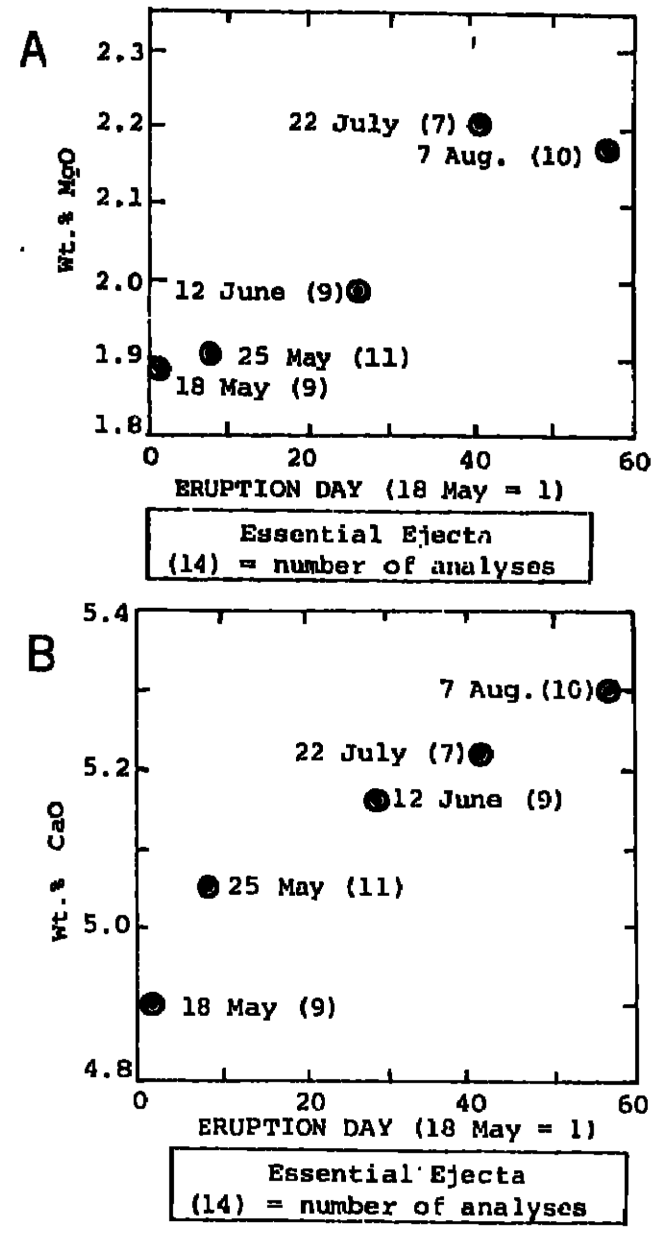


Fig. 1. (*a*) Average MgO and (*b*) CaO concentration in eruptive rocks from each eruptive episode at Mount St. Helens, May 18 to August 7, plotted against time of each episode (May 18 = 1). Analyses are of fused powders by the electron microprobe. Numbers in parentheses are the number of samples analyzed and included for average value.

Information contacts: Tom Casadevall, Chris Newhall, and Don Swanson, U.S. Geological Survey Field Office, 301 E. McLaughlin, Vancouver, WA 98663.

Robert Tilling, U.S. Geological Survey, Stop 906, National Center, Reston, VA 22092.

Steven Malone, Robert Crosson, and Elliot Endo, Graduate Program in Geophysics, University of Washington, Seattle, WA 98195.

William G. Melson, NHB Stop 119, Smithsonian Institute, Washington, D. C. 20560.

Pavlof Volcano, Alaska Peninsula, Alaska, U.S.A. (55.42°N, 161.90°W). All times are local (GMT − 10 h). An eruption from Pavlof November 11–12 ejected large lava fountains and ash clouds that reached 11 km altitude and may have produced lava flows.

A seismic station 10 km southwest of Pavlof registered a $2^1/_2$ min burst of low-amplitude harmonic tremor beginning on November 5 at 1351. Emission of steam, ash, and some blocks from a vent high on the northeast flank started November 8 at 1047 and lasted about 5 min, without accompanying seismicity. A second burst of low-amplitude tremor

TABLE 1. Averages for Each Eruptive Episode of Mount St. Helens, May 18 to August 7

Number	SiO_2	Al_2O_3	FeO*	MgO	CaO	K_2O	Na_2O	TiO_2	P_2O_5	MnO	Sum
1	64.13	17.61	4.04	1.88	4.90	1.26	4.63	0.56	0.15	0.00	99.16
2	64.19	17.92	3.99	1.91	5.06	1.29	4.83	0.60	0.15	0.00	99.94
3	63.72	18.04	4.24	1.99	5.16	1.25	4.70	0.64	0.15	0.00	99.89
4	63.49	17.87	4.44	2.20	5.22	1.26	4.97	0.57	0.15	0.00	100.17
5	63.28	17.51	4.39	2.17	5.30	1.23	4.89	0.64	0.16	0.00	99.57

Electron microprobe analyses of fused powders by W. Melson, T. O'Hearn, and J. Nelen, Smithsonian Institution. Samples collected by D. Swanson, C. Hopson, W. Melson, R. Fiske, and C. Kienle.

1, May 18 average nine analyses; 2, May 25 average 11 analyses; 3, June 12 average nine analyses; 4, July 22 average nine analyses; 5, August 7 average 10 analyses.

*Total iron calculated as FeO.

occurred between 0536 and 0541 on November 9.

In contrast to the pattern observed before eruptions in 1973, 1974, 1975, and 1976, virtually no additional seismic activity was recorded until a group of seven low-frequency volcanic earthquakes occurred at about 2300 on November 10. After an explosion event appeared on seismic records at 0243 on November 11, 10 more low-frequency volcanic earthquakes were recorded between 0300 and 0400. Continuous harmonic tremor, of fairly low amplitude, began at 0608, but amplitude intensified around 0900.

Reeve Aleutian Airways pilot Everett Skinner saw rocks up to 1 m in diameter rising 10 to 30 m at 1315 on November 11. An observer in Cold Bay, 60 km to the West, noted an increase in activity about 1600. Skinner returned to the vicinity of Pavlof between 1630 and 1700, reporting lava fountaining from the summit, a black cloud hugging the volcano's upper north flank, and an eruption column reaching an estimated 6 km altitude. Between 1800 and 2000, various witnesses reported lava fountaining to a maximum height of 300 m and incandescent material moving down the north flank. A satellite image returned at 1958 shows a nearly circular plume, 15 km in diameter, north of the volcano. Activity was visible through the night from Cold Bay (see above) and the Sand Point area (50–65 km to the east northeast).

The next morning, at 0946, a satellite image revealed a plume 160 km long and almost as wide spreading north of Pavlof. Spectral analysis and weather balloon data indicate that the plume reached 8–9 km above sea level. Pilot reports on November 12 placed the top of the eruption cloud at 9 km at 1000, 6 km at 1100, and 11 km at 1400. The eruption clouds were described as varying from ash-rich to ash-poor. A helicopter crew from KENI television, Anchorage, videotaped pulses and bursts of lava fountaining, rising 150–300 m between 1600 and 1700. The fountains emerged from a preexisting vent high on the northeast flank, the only vent confirmed active during the eruption.

Very high amplitude harmonic tremor accompanied the eruption, reaching its strongest levels between 2000 on November 11 and 0700 on November 12. Tremor ceased at 1835 on November 12, at which time many B-type earthquakes began to be recorded.

By the morning of November 13, the eruption had ended. Several hundred B-type events per day were recorded November 14–15. Renewed high-amplitude tremor began November 15 at 1306, lasting until 1711. B-type earthquakes continued November 16–19, but fewer than 100/day were recorded.

Information contacts: S. McNutt and J. Davies, Lamont-Doherty Geological Observatory, Palisades, NY 10964.

Alison Till, U.S. Geological Survey, 1209 Orca St., Anchorage, AK 99501.

Jürgen Kienle, Geophysical Institute, University of Alaska, Fairbanks, AK 99701.

G. Roberts, Cold Bay Weather Station, Cold Bay, AK 99571.

Commander John Hair, Chief, Marine Environmental Branch, P.O. Box 3-5000 (MEP), Junoau, AK 99802.

Gareloi Volcano, Aleutian Islands, Alaska (51.80°N, 178.80°W). All times are local (GMT − 10 h). On August 10 and 11, SO_4^{-} from a fresh volcanic plume was detected from a research aircraft (flown by NASA under contract from the U.S. Department of Energy) at 19.2 km altitude just south of Anchorage, Alaska.

Imagery returned August 8 at 1010 by the NOAA 6 Satellite shows a high-altitude plume appearing to originate from the vicinity of Gareloi. Using a drift rate of 30 km/hr, Los Alamos Scientific Laboratory personnel calculated that the eruption which produced this plume had probably ended about 10 h earlier. Later visual and infrared images show the plume moving toward the Anchorage area, about 2000 km from Gareloi, at a rate that could have brought it to the sampling area by August 10. The eruption column seen emerging from Gareloi August 9 by a commercial pilot was also present on satellite images, but clearly was not large enough and did not reach a high enough altitude to have been the source of the material sampled August 10–11. Wind conditions also preclude the August 7 eruption clouds from Mount St. Helens as a source for SO_4^{-} in the Anchorage area at this time.

Information contacts: W. A. Sedlacek, G. H. Heiken and E. J. Mroz, Los Alamos Scientific Laboratory, Los Alamos, NM 97545.

Kralla Caldera, Myvatn Area, Iceland (65.71°N, 16.75°W). The following is a report from Karl Grönvold.

After the October eruption the magma reservoirs at Kralla inflated rapidly until the last week of November. Ground level monitoring indicates that at that time land height over the magma reservoirs was higher than before the October eruption. During the week or so prior to 3 December, the rate of inflation has been slower and more irregular.

From the pattern of behavior so far, an eruption can be expected to take place soon. Evacuation plans and civil defence measures have been strengthened in case of an eruption in the southern part of the fissure system, closer to the village near Lake Myvatn.

Information contact: Karl Grönvold, Nordic Volcanological Institute, University of Iceland, Reykjavik, Iceland.

Langila Volcano, New Britain Island, Papua New Guinea (5 53'S, 148.42°E). The following is a report from the acting senior volcanologist.

Intensified eruptive activity that began in mid-October continued until 8 November. Dark emission clouds continued to be released from crater 2, and emission clouds from crater 3 were pale gray. Ejections of incandescent lava fragments from both craters were accompanied by rumblings and explosion sounds. The lava flow from crater 3 was reported to be still active on 11 November.

A decline in the intensity of the eruption was evident on 8 November, when seismograph attenuation was reduced by 18 decibels. However, glows and ejections of incandescent lava fragments continued from both craters, and gray ash and vapor clouds continued to be emitted.

Information contact: Acting senior volcanologist, Rabaul Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Kevachi Volcano, Solomon Islands, Southwest Pacific (9.03°S, 157.93°E). Solair pilots flying over Kevachi Volcano on October 14 observed a similar submarine eruption to that reported by Chief Pilot Bruce Kirkwood on October 7, although there appeared to be more mud in the surrounding seas than during the earlier activity. By October 23, activity had decreased to occasional bursts of hot water at the surface.

Information contact: Deni Tuni, Geology Division, Ministry of Natural Resources, Honiara, Solomon Islands.

Volcanic Activity in the Philippines, September–November

Bulusan Volcano, Luzon Island (12.77°N, 124.05° E). Bulusan's most recent ash eruption, on September 28, was followed by a series of volcanic earthquakes which became less frequent with time. Felt events of intensity I to II on the Modified Rossi-Forel Scale have also occasionally been recorded.

Mayon Volcano, southeast Luzon Island (13.26°N, 123.62°E). Short-duration harmonic tremor was first noted at Mayon on August 16. Occasional tremor continued through November, and as of November 30, 214 episodes had been recorded. Similar seismicity preceded the 1978 eruption and accompanied crater glow in July 1979.

Canlaon Volcano, Negros Island (10.41°N, 123.13°E). Seismic activity at Canlaon has lessened considerably since it started on May 6, 1980, but remained above normal as of late November. Canlaon last erupted in mid-1978, ejecting ash intermittently.

Information contact: Olimpio Peña, Acting Commissioner, Commission on Volcanology, 5th floor, Hizon Bldg., Quezon Blvd. Ext., Quezon City, Philippines.

Myojinsho Submarine Volcano, Mariana Islands, Japan (31.92°N, 139.92°E). All times are local (GMT + 9 h). The crew of the fishing boat *Suitenmaru 11* saw discolored water over Myojinsho on November 15 at around 1530. They reported that no discoloration had been seen there that morning. Personnel from the Japan Maritime Safety Agency (JMSA) flew over the site on November 18 and observed three circular areas of pale green water, each 50–80 m across, aligned within a 300-m zone. These were also seen the following day by the crew of the fishing boat *Shinkomaru 26* and again by JMSA personnel on November 26. No floating ejecta or upwelling of water were noted, however.

The November activity is the first since July 13, 1979, when JMSA observed discolored water. In 1952, 31 persons aboard the research vessel *Kaiyo Maru 5* were killed by a violent phreatic eruption of Myojinsho.

Information contacts: Japan Maritime Safety Agency, 5-3 Tsukiji, Chuo-ku, Tokyo, Japan.

Seismological Division, Japan Meteorological Agency, 1-3-4 Otemachi, Chiyoda-ku, Tokyo 100, Japan.

Submarine Volcanoes, Volcano Islands, North Pacific Ocean. The Japan Maritime Safety Agency (JMSA) continues frequent monitoring flights over several known submarine volcanoes (see table below). The most active of these Fukutoku-oka-no-ba (24.28° N, 141.52° E), formed islands in 1904 and 1914, and discolored sea water in 1950, 1952–1953, 1955–1956, 1958–1959, 1962, 1967–1968, and 1973–1980. Discoloration has also been seen occasionally over Fukujin (21.93° N, 143.47° E) each year since 1977. Minami-hiyoshi (23.50° N, 141.90°E) discolored seawater January–March 1977 and January–March 1978, but has not been active since. An adjacent vent, Nikko (23.08° N, 142.32° E) has shown no signs of activity since July 1979. (See Table 2.)

Information contacts: Same as for Myojinsho.

TABLE 2. Volcanic Activity at Three Sites in the Volcano Islands, April to October, 1980

Date of Observation	Fukutoku-oka-no-ba	Minami-hiyoshi	Fukujin
April 24	D	N	N
May 12	D	—	D
June 16	D	N	N
July 7	D	—	—
July 8	D	N	N
July 14	D	N	N
August 18	N	N	N
September 4	N	N	N
October 21	N	N	N

D, discolored water observed. N, no discolored water. Blank, no overflight.

Sakurazima Volcano, Kyushu, Japan (31.58°N, 130.65°E). The number of explosions recorded at Sakurazima declined from 21 in September to 4 in October, then increased to 21 in November (see Table 3). The highest October ash cloud reached 2.0 km on the first. None of the October activity caused any damage. Lapilli from the largest November tephra cloud, which rose 2.5 km on November 8, broke five car windshields, The air shock from the November 28 explosion broke two windows in a hotel at the base of the volcano. No injuries were reported.

The November 23 explosion was the 267th of 1980, making the year's total the greatest since 1974.

Information contact: Seismological Division, Japan Meteorological Agency, 1-3-4 Otemachi, Chiyoda-ku, Tokyo 100, Japan.

TABLE 3. Explosions From Sakurazima, October–November 1980

	Number of Explosions
October	
1	1
16	1
19	1
24	1
Total	4
November	
1	2
2	1
3	3
7	2
8	2
9	1
10	1
13	2
22	1
23	2
24	3
28	1
Total	21

Asama Volcano, central Honshu, Japan (36.40° N, 138.53° E). Monthly seismicity at Asama increased from 1114 recorded events in September to 1350 in October (see Figure 2), the highest monthly total since August 1977. Seismic activity decreased to 897 recorded events in November. No eruption or increase in steam emission were observed. Asama last erupted in 1973, when the number of earthquakes reached 5612 per month.

Information contacts: Same as for Sakurazima.

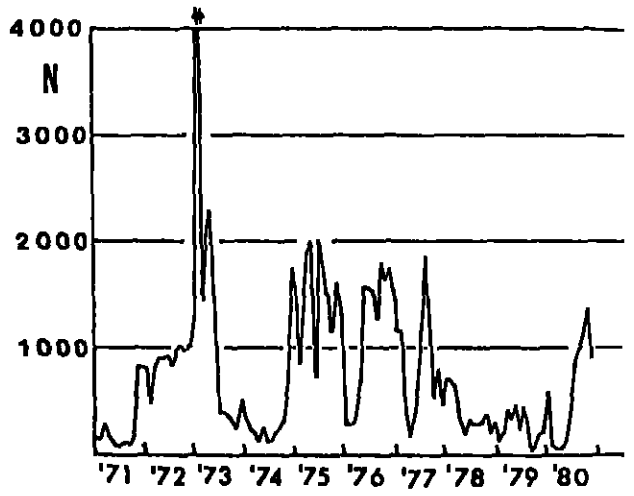


Fig. 2. Number of seismic events recorded per month at Asama, January 1971 to November 1980. The eruptions of February and March 1973 are indicated by arrows at the top of the figure.

Earthquakes

	Time, GMT	Magnitude	Latitude	Longitude	Depth of Focus	Region
Nov. 8	1028	7.4 M_s	41.16°N	124.34°W	14 km	off the coast of north California
Nov. 11	1037	6.9 M_s	51.43°S	28.84°E	10 km	Atlantic-Indian Ridge south of Africa
Nov. 12	0658	5.2 m_b	13.09°S	74.45°W	shallow	south central Peru
Nov. 23	1835	6.9 M_s	40.81°N	15.34°E	6 km	south Italy
Nov. 26	1736	4.7 m_b	8.10°N	72.22°W	shallow	east Venezuela

The California earthquake caused a bridge collapse that injured six persons, but damage was generally light and no other injuries were reported. The Peru shock killed at least seven people, injured at least 20 others, and left thousands homeless. Casualties and damage were concentrated in the San José area, 80 km east of Ayacucho. About 25,000 km² of south Italy were devastated on November 23. As of early December, official casualty figures listed 3105 as killed, 1575 missing, and presumed dead, and 1671 injured. An estimated 200,000 were left homeless. The November 26 event injured 36 people and badly damaged 30 buildings in Cucuta, Colombia, on the Venezuelan border.

Information contacts: National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, CO 80225.

Reuters.
United Press International.
The Associated Press.
The New York Times.

Fireballs

Atlantic Ocean, November 15, 2300 GMT.
Observer: Capt. Zweigler, F/O Graf, F/E Kogelnig of Lufthansa Flight SN 519, (Caracas - Frankfurt).
Location: 22.45°N, 48.15°W, aircraft course 031° magnetic, altitude 8.8 km.
First sighting: 76° magnetic, 30° above horizon.
Last sighting: 91° magnetic, 10° above horizon.
Duration: 20 s.

Apparent brightness: like full moon.
Color: white at the beginning, yellow at the end.
Size: about half of the full moon.
The object initially possessed a smoky tail about 4 times the length of its head. When last seen, the fireball was separating into four or five pieces. A yellow afterglow lingered for 5–7 s.

Information contact: Gerhard Polnitzky, Universitaets-Sternwarte, Tuerkenschanzstrasse 117, A-1180 Wien, Austria.

Atlantic Ocean, November 17, 0106 GMT.
Observers: Capt. Helle, F/O Behrendt, F/E Schmidt of Lufthansa Flight LH 421, (Boston - Frankfurt)
Location: 42.53°N, 57.20°W, aircraft course 065° true, altitude 9.4 km.
First sighting: 065° true, 40° above horizon.
Last sighting: 045° true, 5°–10° above horizon.
Duration: 3 s.
Apparent brightness: like full moon.
Color: blue-green, then yellow-red.
Size: 1/4 of full moon.
Information contact: same as above.

Austria, August 11, 2159 GMT.
Observer: K. Franger.
Location: Gloggnitz, Austria (47.68°N, 15.97°E).
First sighting: right Ascension 21 h 20 min declination +67°.
Last sighting: right Ascension 18 h 45 min declination +40°.
Duration: 12 s.
The fireball was first observed in the constellation Cepheus and disappeared in Lyra. It had an initial magnitude of −2, intensifying to −8 on explosion of the bolide. At this point, the shadows of nearby trees could be clearly seen. No noise was heard. An afterglow was visible for 10 s.
Information contact: same as for Atlantic Ocean.

Czechoslovakia-Poland border, October 3, 2300–2400 GMT. The following is a report from Zdeněk Ceplecha.

A fireball of −10 maximum absolute magnitude was photographed by at least 2 stations of the European network. The fireball traveled a 52 km luminous trajectory in 2.8 s. No visual observations are available and the time of fireball passage is rather uncertain. The following results are based on 2 photographs of the Czech part of the network.

	Beginning	Maximum Light	Terminal
Velocity (km/s)	18.6	17.6	16.7
Height (km)	73	48	43
Latitude	49.39°N	49.61°N	49.64°N
Longitude	18.73°E	19.11°E	19.18°E
Magnitude	−4	−10	−4
Mass (kg)	9.8	1.3	0
Z R	56.0°	56.0°	58.0°

Fireball type: II.
Meteorite fall very improbable.

Radiant (1950.0)	Observed	Geocentric	Heliocentric
Alpha	345°	341°	—
Delta	4°	−2°	—
Lambda	—	—	301°
Beta	—	—	2°
Initial velocity (km/s)	18.6	15.2	39

Orbit (1950.0)	
A	4.0 A.U.
E	0.8
Q	0.86 A.U.
Aphelion	7.0 A.U.
Omega	227.0°
Ascending node	190.45°
Inclination	2.0°

Meteor shower: perhaps a bright member of Capricornids.
Information contact: same as Czechoslovakia-Austria.

Czechoslovakia-Austria border, November 18, 011332 GMT. The following is a report from Zdeněk Ceplecha.

A fireball of ~12 maximum absolute magnitude was photographed by 6 Czech stations of the European network. The fireball traveled a 53 km luminous trajectory in 0.7 seconds. A prism spectrum with dispersion of 20 nanometers (nm)/mm in the blue region was photographed from the Ondřejov Observatory. The strongest lines belong to ionized calcium (393–397 nm), ionized magnesium (448 nm) and ionized silicon (635–637 nm) and to neutral sodium (589–590 nm). Most of the medium and faint lines belong to neutral iron, magnesium, and calcium. The following results are based on all available photographs and should be close to final values.

	Beginning	Maximum Light	Terminal
Velocity (km/s)	71.9	70.8	69.0
Height (km)	117.3	91.8	87.5
Latitude	48.621°N	48.850°N	48.855°N
Longitude	15.838°E	15.328°E	15.248°E
Magnitude	−3.8	−12.0	−4.2
Mass (kg)	0.19	0.02	none
Z R	56.8°	—	56.2°

Fireball type: III A I.

Typical cometary fireball belonging to the Leonid Meteor Shower (Parent Comet: Tempel-Tuttle). Meteorite fall impossible.

The increase in brightness during the first half-second corresponds to 17 stellar magnitudes per second (6 million times per second in light intensity), which is the biggest increase of brightness we ever observed for a fireball photographed within the European network. The sudden decrease of brightness after the maximum light corresponds to 100 stellar magnitudes per second.

Radiant (1950.0)	Observed	Geocentric	Heliocentric
Alpha	153.7°	153.8°	—
Delta	22.04°	21.88°	—
Lambda	—	—	149.1°
Beta	—	—	17.7°
Initial Velocity (km/s)	71.9	70.8	41.5

Orbit (1950.0)	
A	13 (±3) A.U.
E	0.92
Q	0.9845 A.U.
Aphelion	25 (±6) A.U.
Omega	172.7°
Ascending node	235.4483°
Inclination	162.2°

Information contact: Zdeněk Ceplecha, Ondřejov Observatory, 251 65 Ondřejov, Czechoslovakia.

South Europe, November 11, 1736 GMT. Many persons in Austria and Italy observed a brilliant fireball that traveled from northeast to southwest, disappearing below the southwest horizon. Table 4 summarizes a few of the observations. None of the observers reported any sounds.

Information contacts: Maurizio Eltri and Enrico Stomeo, Via Marcantonio Bragadin No. 2, 30126 Lido, Venezia, Italy.

Gerhard Polnitzky, Universitaets-Sternwarte, Tuerkenschanzstrasse 17, A-1180 Wien, Austria.

Iraq, October 5, 2256 GMT (October 6, 0156 local time).
Observers: Capt. Schatzmann, F/O Meier, F/E Keller of Swissair Flight SR 198 (Athens-Bombay).
Location: Iraq (33.33°N, 38.30°E), aircraft course 120° magnetic, altitude 10 km.
First sighting: 125° magnetic, 10° above the horizon.
Last sighting: 130° magnetic, at the horizon.
Duration: 2 s.
Brightness: dazzling.
Color: blue-white.
Size: about 1/4 of the full moon.
No tail was observed.
Information contact: Gerhard Polnitzky (see above).

California, U.S.A., November 12, 0350 GMT (November 11, 1950, Pacific Standard Time). Mr. and Mrs. Robert Dickey of San Juan Capistrano (33.50°N, 117.63°W) observed a brilliant fireball during an evening of moderate cloud cover. The object first appeared as a very bright flash along the meridian at a point near the ecliptic, before descending rapidly to the Southeast and disappearing near the visual horizon at about azimuth 120°. The entire event lasted between 3 and 4 s. Varying cloud thicknesses along the flight path caused brightening and darkening. Brightness was most intense during the initial flash, several times that of the full moon.

Information contact: Robert Dickey, Bob Dickey Geotechnical, Inc., 32145 Via Carlos, P.O. Box 694, San Juan Capistrano, CA 92675.

Massachusetts, U.S.A., November 21, 1414 GMT (0914 Eastern Standard Time). David Folger saw a very bright daylight fireball from Woods Hole, Massachusetts. The object, which first appeared in the northern sky as a single blue-green ball with tail, passed through approximately 10° of arc, descending west to east at an angle of at least 30°. In midflight, the bolide broke into two pieces, both with tails, before disappearing 30°–40° above the horizon. The complete event lasted about 1 s. No fireball sounds were heard, but they may have been masked by other loud noise near the observer.

Information contact: David Folger, Chief, Atlantic-Gulf Branch (Marine Geology), U.S. Geological Survey, Woods Hole, MA 02543.

West Texas, U.S.A., September 20, 0220 GMT. (September 19, 2120 Central Daylight Time).
Observer/Location: Ed Walraven, near San Antonio, Tom Green County, west Texas (31.2°N, 100.7°W), Ronald Schorn and Michael Courtney, near College Station, Brazos County, east Texas (30.6°N, 96.3°W).
Flight path: near vertical, ending almost at the horizon.
Duration: 2–3 s.
Apparent magnitude: −8 to −10.
Color: yellowish-white with red end.
R. Schorn, an astronomer, believed that the velocity was sufficient to rule out man-made debris falling out of orbit and that a meteorite fall was possible.
Information contact: John West, 3502 Old Oaks Drive, Bryan, TX 77801

TABLE 4. Observations for South Europe, November 11

Observer	Location	First Sighting	Last Sighting	Duration	Magnitude	Color	Size	Train
—*	60 km northwest of Klagenfurt, Austria (47.2°N, 13.6°E)	190° magnetic, 40° above the horizon	210° magnetic	30 s	like a pyrotechnical flare	white, becoming red	1/4 of moon	persisted 4 min
—	Venice, Italy (45.4°N, 12.3°E)	NE sky	SW horizon	—	~−9	white-blue	—	none persisted
Tesi Luciano	south Marcello, Italy (44.05°N, 10.78°E)	NE sky	SW horizon	—	−11 to −12	white-blue with green-red halo	—	none persisted
P. Fapperdue	Viterbo, Italy (42.4°N, 12.1°E)	NNE, 50° altitude	SW horizon	10 s	−17	orange	—	wavy train persisted 2–3 s
—	Rome, Italy (41.9°N, 12.5°E)	—	—	—	−15	red-green with white center	—	20°–30° long

*Capt. Hanisch, F/O Pillz, F/E Heptner, F/E Hoehe of Lufthansa flight LH 605 (Tel Aviv–Frankfurt).

New Publications

Applied Water Resource Systems Planning

D. C. Major and R. L. Lenton, Prentice-Hall, Englewood Cliffs, N.J., viii + 248 pp., 1979, $19.95.

Reviewed by Richard N. Palmer

Design of Water Resource Systems, authored in 1962 by Maass, Hufschmidt, Dorfman, Thomas, Marglin, and Fair (Harvard University Press, Cambridge, Massachusetts) helped to introduce a new perspective in water resource planning. This seminal text, a product of the Harvard Water Program, combined economics and systems analysis with more conventional engineering procedures to produce new methodologies for the evaluation and design of water resource projects. Until this time few practitioners or academicians, allowing for several notable exceptions such as Arthur Morgan and Abel Wolman, had taken as careful and comprehensive a view of the process of water resource development and management. Over the years this text has had a significant influence on other water resource planners and the manner in which they approach problem solving.

In an new text entitled *Applied Water Resource Systems Planning*, this influence is clearly illustrated. Together with 14 coauthors, editors David Major and Roberto Lenton present a successful application of the theory and the techniques suggested by Maass et al. in a study of river basin development in the Rio Colorado in Argentina. The study described in the book was conducted in the mid-1970's at the request of the Argentine government by a team of researchers from MIT and government officials from Argentina. The research performed three primary purposes: to adopt water resource planning techniques to Argentina, to train Argentine professionals in their use, and to apply the techniques to the Rio Colorado. The book focuses on the third of these purposes.

The twelve chapters are divided into three parts. Part 1 gives an excellent background to the problem setting, a description of the methodology used, and an overview of the remaining portions of the book. Part 2 describes four mathematical models developed to analyze the problem. Part 3 presents parameter inputs for the model, the results, the interpretations, and the perspectives. Following several of the chapters are appendices that describe in further detail topics presented in the chapters.

The problem addressed in this book was how best to plan for the future development and sequencing of a number of potential hydropower facilities, irrigation systems, and reservoir projects in the Rio Colorado and surrounding basins. The researchers approached their problem with two tools advocated by Maass et al.: mathematical programing and multiobjective economic evaluation. The methodology they developed to solve the problem was a series of mathematical models, differing in purpose and in complexity, that were used sequentially to evaluate potential system configurations. These models are described in chapters 5, 6, and 7. A mixed integer screening model was used to select potential development at 38 sites in the basin. Hydrologic input consisted of monthly streamflow data. Potential system configurations generated by the screening model were then tested in one of two simulation models. These simulation models differed in the degree to which the hydrologic system was described and the length of time steps used. The time steps ranged from 4 months to 1 hour increments. (Apparently, the more detailed of the two simulation models grew to such proportions that it became very expensive to use and was therefore used sparingly.) Finally, systems that appeared most favorable were investigated by using a

sequencing model that optimized investment over a 40-year time horizon. Because of the massive scale of the system, some important components were ignored. For instance, each reservoir was considered as an independent entity, and no attempt was made to derive an optimal operating policy for the system as a whole.

The book is clearly organized and well written throughout. Despite the numerous authors, the writing is surprisingly uniform in style and is highly readable. Terminology and notation, except where noted, seem to be totally consistent. In short, there is never the feeling of a disjointed effort which is common among most books with multiple authors. Good references at the end of each chapter allow the reader to pursue topics of interest. The descriptions of the mathematical models developed in this study are exceptionally clear and concise. Of special value are the discussions that relate the various models and illustrate how the models are used to complement one another.

In addition to its numerous positive attributes, however, the book does contain flaws. These flaws are the most striking when the book is viewed as a potential text, as is suggested in the introduction. The introductory chapters that discuss multiobjective planning and mathematical modeling (chapters 2 and 3) are superficial and do not lay the necessary foundation for the techniques that are used in the following chapters. Interested readers must seek the material that is referenced to obtain a complete appreciation of these topics. Insufficient emphasis is placed on the process of model development and on model interpretation. The restricted number of approaches and techniques that are presented in the book prevents it from being a well rounded introductory textbook in water resource systems. At the other extreme, the models presented in the text can no longer be considered state of the art and are not given in sufficient detail to allow the book to be used as a basic reference or as an advanced graduate text.

Despite the above criticisms, Major and Lenton's book would make an excellent supplemental text in an introductory course in water resources planning. Viewed as a case study, the book illustrates the valuable process of transforming a complex water resource problem into a system of objectives and constraints that can be quantitatively analyzed and, eventually, improve the planning process.

Richard Palmer is with the Department of Civil Engineering, Water and Air Resources Division, University of Washington, Seattle, Washington.

Marine Turbulence

J. C. J. Nihoul, Elsevier, New York, xii + 378 pp., 1980, $58.50.

Reviewed by John Woods

There has long been a conspiracy among fluid dynamicists of an engineering inclination to reserve the word 'turbulence' for a very special type of nonlinear fluctuations in which three-dimensional vortex stretching drives a cascade of kinetic energy from large scale to small, often with virtually no flux divergence over some portion of the spectrum. The study of such three-dimensionally isotropic (3DI) turbulence has made a major contribution in engineering, but after 75 years of research it is clear that life is more complicated in the ocean, where mixing is normally dominated by nonlinear fluctuations that are not characterized by three-dimensional vortex stretching and are at best only two-dimensionally isotropic (2DI). Rejecting the use of the term turbulence for such important oceanic motion, one of the leading conspirators insists on using the vivid, if rather rude, term 'flatulence.' This arrogant nonsense has prevailed because the engineers have until recently cornered the market in textbooks and monographs on turbulence.

At last the situation is changing. The development of new tools to measure the fluctuations in the motion and scalar concentrations in the ocean has stimulated theoretical and laboratory studies designed to improve our understanding of the phenomenon of ocean turbulence in its own right, rather than as a minor application of engineering turbulence. Monographs are beginning to emerge.

The volume under review represents a collection of 21 papers presented at the 11th International Colloquium on ocean hydrodynamics (Liège, May 1979). The Colloquium was held in association with the second IDOE-IAPSO Symposium on 'Turbulence in the Ocean.' Another book, containing commissioned review papers presented at the symposium will be published soon. The two volumes neatly complement each other: The present volume contains papers reporting results of research projects, while the latter will contain broader reviews. Both contain material covering the whole spectral range encountered in the ocean, from millimeters to megameters. Nihoul, in an introductory chapter to 'Marine Turbulence,' identifies the features that distinguish what we find in the ocean from what the engineer finds in his/her world. The key factor is that, in the interior of the ocean (i.e., away from the boundary layers), almost all the turbulent kinetic energy occurs as motions with large Richardson number and small Rossby number. Classical 3DI turbulence occurs only at scales (~1 m) much smaller than that of structure in the mean circulation, so there is a spectral gap several decades wide between the input of turbulent kinetic energy and its entry into the 3DI turbulence that can whisk it speedily to molecular dissipation. Very little energy succeeds in leaping this gap, with the result that 3DI turbulence occurs only sporadically in short-lived bursts in otherwise laminar flow. The central problem of turbulence in the interior of the ocean is to understand the processes occurring at high Richardson number/low Rossby number.

How do the eddies, fronts, and fine structure relate to each other and to the Rossby and internal buoyancy waves propagating through them? Panchev summarizes the contribution of classical 2DI turbulence theory to this problem, following the approach of his well-known monograph. One of the themes to emerge from discussions at the Liège meeting was the need to take an integrated view in which all these motions, waves included, contribute to the overall budgets of the variances of momentum, vorticity, temperature, salinity, etc. It is therefore entirely consistent to find papers by Colin de Verdiere on Rossby waves and Orlanski and Cerasoli on internal waves. There is no contribution in this volume on the eddies (perhaps because they will be treated extensively in a monograph now being edited by Alan Robinson), but Fedorov reports on a case study designed to illuminate the complicated phenomenon of front-line structure interaction. That takes us up to page 100.

The remaining 278 pages are devoted to papers on the occurrence of 3DI turbulence in the ocean, mainly in the boundary layers. This is probably a fair balance in terms of effort in the research community, but not, I would have thought, if judged in terms of either the proportion of the spectrum covered by 3DI turbulence (about 0.001%) or in terms of practical applications, almost all of which lie at large scale.

But, brushing aside these reservations, let us see what topics are included. The first theme is the cascade of kinetic energy to molecular dissipation, with contributions from Dillon and Caldwell (abstract only), Oakey and Elliott (documenting the correlation between the wind speed and dissipation in the wind mixed layer), Osborn (measurements below the wind mixed layer), and Ozmidov (ditto). There is still some uncertainty about the interpretation of the microscale measurements on which dissipation estimates are based; there are inconsistencies with measurements of scalar variance spectra (represented here by Gregg and by Gibson). The next theme is the generation of 3DI turbulence in the interior of the ocean by shear instability (field evidence from Belyaev) and double diffusive instability (fascinating theoretical expositions by Lumley, and by Piacsek and Toomre, in which we see a geophysically important phenomenon simulated on a computer by a numerical model that has no need to parameterize unresolved fluid motion). Naturally, many contributors are concerned with the turbulence in boundary layers. Revault d'Allonnes and Caulliez present a progress report on measurements from the Bouée Laboratoire, which can be compared with Dillon and Caldwell data already mentioned. Five papers deal with the bottom boundary layer in the presence of strong tidal currents. Bowden and Ferguson measured the vertical profile of shear stress by the eddy correlation method; and for the same area, Wolf estimated very similar shear stress values from external data and Swift used an analytical model with tidally varying turbulent kinetic energy to calculate residual currents. Then come two papers on the shear effect on dispersion in tidal flow, by Nihoul, Runfola and Roisin and by Warluzel and Benque. The final contribution, by Veth, describes a new tool—the laser-Doppler velocimeter—that may make a significant contribution to ocean turbulence observations in the future.

Conference proceedings tend to be rather patchy, and this is no exception, but *Marine Turbulence* contains much useful material and is recommended not only to those in the business, but also to the general oceanographer and, yes, to those who still believe in the restricted engineering definition of turbulence.

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Marine Geodesy, vol. 3, nos. 1-4

N. K. Saxena (Ed.), *Special Issue on Interaction of Marine Geodesy and Ocean Dynamics*, Crane, Russak, New York, 436 pp., 1980, $48.00.

Reviewed by David Wells

A symposium on the 'Interaction of Marine Geodesy and Ocean Dynamics' was held in Miami, Florida, October 10–13, 1978. The symposium was sponsored by AGU and six other organizations and consisted of four technical sessions, four concurrent workshops, and a final plenary workshop. These proceedings contain a summary of the workshops and 15 out of the 28 papers presented during the technical sessions.

The interactions between marine geodesy and ocean dynamics considered in these proceedings separate into the horizontal (a one-way interaction, the provision of precise positioning by marine geodesists to ocean dynamicists), and the vertical (two-way interactions in several common-interest aspects of sea surface height). The interactions are most intimate in the analysis of satellite-borne radar altimetry, which senses the instantaneous sea level, as affected by both the marine geodesists' 'signal' (the marine geoid) and by the ocean dynamicists' signals (variously due to tides, currents, storm surges, wind, and atmospheric disturbances). This intimate interaction, in which for each the signal of the other is often noise, is well represented in the content of these proceedings.

The horizontal interaction is considered in two papers. Halsip reported on the status of radio navigation systems maintained by the U.S. Coast Guard. Seeber presented results from two Transit Satellite Doppler studies, on the effect of drilling rig metal decks on height determination, and on the feasibility of precisely tracking moored buoy movements.

The vertical interaction is represented by three groups of papers concerned with ocean circulation, global ocean tides, and the marine geoid.

Gatto used remote sensing techniques to determine circulation patterns. Papers by Chew and by Molinari discuss currents in the Florida Straits and in the Caribbean Sea and in Gulf of Mexico, respectively, each touching (inconclusively) on the controversial interaction between steric and geodetic leveling.

Global ocean tide (GOT) models are of practical interest in the analysis, for example, of satellite altimetry data, satellite orbit perturbations, and seabed gravimetry. Zetler traced the complementary developments of GOT models and of pelagic (ocean bottom) tide gauges, data from which are invaluable for testing and tuning GOT models. Three approaches to GOT models were described by Schwiderski (in two papers), Parke, and Estes. In the first two cases, a theoretical model was used to interpolate between tidal data from coastal and island stations. The Transit constituent obtained by Schwiderski agreed with the M_2 constituent from independent pelagic data to within 2 cm in amplitude and 6° in phase. Parke presented maps of some geophysically useful parameters derived from modeled M_2, S_2, and K_1 constituents. Estes presented a purely theoretical GOT model (independent of island or pelagic tidal data) and used it in a simulation of the effect of unmodeled systematic orbit errors on the problem of extracting ocean tide information from satellite altimetry.

Determination of the marine geoid from satellite altimetry is discussed in four papers. Marsh showed that in the short term (treating sea surface heights owing to dynamic effects as noise) altimetry is useful in reducing geoid uncertainties. Brace compared altimetric geoid heights with heights from several geopotential coefficient sets and altimetrically derived mean gravity anomalies with those from marine gravimetry. Torge presented a gravimetric geoid for the North Sea and compared it to one derived from altimetry. For the longer term, an integrated approach to extracting both geoid and dynamic signals from altimetry is needed. Parra used results from the western North Atlantic to show that gravimetric geoids can be corrected in local areas free of permanent geostrophic features and that the study of temporal variations in quasi-steady dynamic features is the most useful contribution of altimetry to ocean dynamics.

GEOS-3 altimetry was used for all the altimetric studies reported here. McArthur described the more advanced SEASAT-1 altimeter, together with proposed future improvements. Ironically, the failure of SEASAT-1 was announced during this symposium.

An introductory paper by the conference cochairmen and session chairmen summarizes the workshops, which dealt almost exclusively with the altimetric connection between marine geodesy and ocean dynamics. This is an excellent tutorial paper on the present and potential uses of this new tool, full of ferment and excitement and occasionally contradictory. (One workshop concluded that mesoscale eddies can be studied with existing altimetry; another workshop concluded that altimeter performance must first be improved considerably.)

Appearing in a refereed journal, these proceedings are certainly more accessible, and perhaps more carefully considered in content, than if they had been produced in a less formal way. The full flavor of the symposium is elusive, however, since nearly half of the papers presented are neither printed nor even listed by title in these proceedings. In particular, more could have been included on sea level variations from ocean dynamics effects other than tides. Nevertheless, the papers here represent a valuable and much needed contribution to our understanding of the interactions between marine geodesy and ocean dynamics and to the dialogue between marine geodesists and ocean dynamicists.

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Applicants should submit resumé and arrange for three letters of recommendation to be sent to James E. Sorauf, Chairman, Department of Geological Sciences, State University of New York at Binghamton, Binghamton, NY 13901.

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Professor Walter Weyhmann, Head
Department of Physics
University of Minnesota
116 Church Street, S.E.
Minneapolis, Minnesota 55455

The candidate should arrange to have at least three letters of recommendation sent directly to the above address. The deadline for receipt of all material is February 1, 1980.

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D. R. Wones, Chairman
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Virginia Poly. Inst. and St. Univ.
Blacksburg, VA 24061

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Meteorologists and Hydrologists/Saudi Arabia. The School of Renewable Natural Resources, University of Arizona, invites applicants for assignment as faculty members to the Institute of Meteorology and Arid Land Studies, King Abdulaziz University, Jeddah, Saudi Arabia. One year, renewable positions in meteorology and hydrology are available.

1. Ph.D. in meteorology with experience in undergraduate teaching and research. Curriculum includes courses in meteorological instruments and methods of observation, dynamic meteorology, synoptic meteorology, physical meteorology, and climatology.

2. M.S. in meteorology with practical experience in meteorologic operations and undergraduate teaching. Knowledge of WMO procedures.

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Description: The project is funded by the Saudi Arabian government through the U.S.-Saudi Arabian Joint Commission on Economic Cooperation. Administration and logistic support is provided by the U.S. Treasury Department, while the program's implementation is by a contract with the Consortium for International Development. The goal of the project is to undertake technical cooperation to develop educational programs for meteorology, hydrology, arid land studies and environmental protection.

Salaries and allowances: Highly competitive with 25% overseas adjustment, housing, car and other allowances.

Availability: February 1, 1981, or soon thereafter for spring semester; September 20, 1981, for fall semester. Initial appointment of one year or more contingent on performance.

Closing date: January 15, 1981 for spring semester; February 15 for fall semester.

Application. The application should include the following. (a) a letter detailing principal qualifications and interests. (b) a curriculum vita. (c) name, address and telephone numbers of three references. Send to Martin M. Fogel, Director, CID/King Abdulaziz University Project, 317A Anthropology Building, University of Arizona, Tucson, AZ 85721, Telephone (602) 626-5344/2989.

EEO/AA employer.

University of New Orleans/Geophysicist. Applications are invited for a permanent faculty position commencing August 1981, in exploration geophysics. The Ph.D. or equivalent experience is required.

Appointee will be expected to teach graduate and undergraduate courses in geophysics and general geology, conduct a program of research, supervise theses and oversee a program in geophysics. The position will be at the assistant professor level or higher depending on background. Applications are encouraged from individuals with industrial experience, including recent retirees.

Applicants should send a letter outlining interest in position, complete resume, and three letters of recommendation to Dr. Gordon Frey, Department of Earth Sciences, Lake Front, University of New Orleans, New Orleans, LA 70122.

UNO is an equal opportunity/affirmative action employer. Applications from minority groups are specifically invited.

Ocean Dynamicist. An academic position (tenure-earning track) for an ocean dynamicist is presently available in the Department of Oceanography, Naval Postgraduate School (NAVPGSCOL). Present or ultimate research interest in area of naval oceanographic concern is desirable. Such areas include: ocean circulation modeling, especially prognostication on the oceanic synoptic scale; surface and internal gravity wave dynamics; synoptic analysis of oceanic data; and acoustical oceanography. The candidate should be willing and able to teach a variety of graduate courses in physical oceanography and related topics. The NAVPGSCOL has excellent computer, data archival, library, and research vessel facilities. The Department of Oceanography has close relations with the Fleet Numerical Oceanography Center, Naval Environmental Prediction Facility, and the Naval Laboratories. The department has a faculty of fifteen and a student body of 80 to 100. The overall emphasis is ocean prediction with present faculty and student research in coastal ocean, polar ocean, and air-sea interaction processes. The academic and research programs are conducted in close collaboration with the Departments of Meteorology and Physics. Salary will be determined by qualifications of the successful candidate. By January 1 if possible, send a curriculum vitae, the names and addresses of three references, and a statement of research and instructional interests to: Faculty Search Committee, Department of Oceanography, Naval Postgraduate School, Monterey, CA 93940. Visits by top candidates will be scheduled soon after. A decision will be attempted by March 1 and the position should be occupied by about June 1, 1981.

The Naval Postgraduate School is an equal opportunity employer.

Research Faculty Position. A faculty position at the research assistant professor level will be available at the Department of Geology, University of Miami from August 15, 1981 (this position will become a tenure-track position on August 1, 1982).

Minimum qualifications are a Ph.D. in the geological sciences, a flair for teaching, and strong research interests as proved in publications.

Areas of specialization (one or more of the following): geochemistry, economic, mineralogy, petrology.

Instrumentation available at the department:

mass spectrometers for $^{13}C/^{12}C$ and $^{18}O/^{16}O$ analysis

mass spectrometers for rare gas analysis ($^{40}K/^{40}Ar$ dating)

a fully equipped radiocarbon laboratory with scintillation counting

atomic absorption units

thermoluminescence unit

video-taping and microcomputer systems

rock thin-sectioning laboratory, petrographic microscopes, stereomicroscopes, etc.

Preference will be given to candidates who would be advantaged by the availability of the equipment listed above for their own research.

Address inquiries to
Cesare Emiliani
Chairman, Search Committee
Department of Geology
University of Miami
P.O. Box 249176
University of Miami Branch
Coral Gables, Florida 33124
tel. (305) 284-4253

The University of Miami is a private, independent, international university.

An equal opportunity employer.

Associate Director/Marine Science Institute. The University of Texas at Austin seeks to fill the open position of associate director of the Marine Science Institute. The associate director is responsible for research and intellectual leadership of the Institute's Galveston Geophysics Laboratory. The position carries the line responsibility of senior administrator for the Galveston Geophysics Laboratory. Duties include research planning and management, fiscal monitoring and budgeting, personnel review and assignment, coordination of scientific programs and shop operations, administrative supervision, liaison with industrial and agency sponsors, representation and other directorship duties.

The Galveston Geophysics Laboratory maintains modern computing facilities, research laboratories, and two deep-ocean research vessels, the R/V Fred Moore and the R/V Ida Green. Research at Galveston includes programs in marine geophysics, marine geology, solid earth geophysics, earthquake and extra-terrestrial seismology, and instrument systems design, both basic and applied.

Applicants are asked to send the following:

(1) Vita—including list of publications.
(2) Brief statement on current research and support.
(3) Brief statement on administrative experience.
(4) Brief statement on teaching experience.
(5) Names of six persons who may be contacted for personal and professional recommendations.

A letter of application and the above requested information should be sent to:

Dr. J. Robert Moore, Director
Marine Science Institute
University of Texas
P.O. Box 7999, University Station
Austin, Texas 78712

Salary based on qualifications. Ph.D. required. The successful candidate will also be considered for tenure appointment in the Department of Marine Studies. Position to be filled as soon as possible. Early application advised. Position located in Galveston, Texas.

An equal opportunity/affirmative action employer.

Sedimentary or Low Temperature Geochemist. This is an assistant professor, tenure track position, although exceptional candidates of higher rank will be considered. We are looking for a geochemist to complement our strong programs in sedimentology, hydrogeology, organic geochemistry, and basin analysis. The teaching load is three courses per year—one beginning level geology course, an upper level geochemistry course, and a graduate course of his/her choosing. Introductory geology and summer field camp are also taught on a long-term rotating basis. A well-equipped laboratory and computer facilities are available. The potential exists both for outside funding and for cooperative research.

The successful candidate will be expected to conduct an active research program leading to publications. Applicants should submit a letter of application, resume, a copy of each transcript, and have three supporting letters sent to:

Chairman
Department of Geology
University of Missouri
Columbia, Missouri 65211

The University of Missouri is an equal employment opportunity employer.

Resource/General Geologist. The University of Pittsburgh at Bradford will have a tenure track opening for a resource or general geologist in September, 1981. This new position will serve an established two-year program in petroleum technology and a new, geology-based, four-year program in environmental sciences. Rank and salary are negotiable. The candidate will be expected to teach introductory or photograph interpretation and at least some of the following courses in the earth and environmental sciences program: structural geology, stratigraphy, economic geology, coal geology. In addition, the candidate will teach courses in the petroleum technology program that are compatible with his or her skills. A Ph.D. and some experience are preferred, but applicants with other qualifications will be considered. Preference will be given to those with petroleum industry experience.

Bradford is located in the Allegheny Mountains in an area rich in natural and recreational resources. Please send resume and three letters of reference to Carl Burgchardt, University of Pittsburgh at Bradford, Bradford, PA 16701.

The University of Pittsburgh is an equal opportunity/affirmative action employer.

Graduate Assistantships/Physics and Astronomy. Graduate research assistantships and teaching assistantships in the Department of Physics and Astronomy of the University of Iowa are available to well-qualified students. The department has vigorous research programs in space physics, plasma physics, acoustics, astronomy, astrophysics, atomic physics, elementary particle physics, laser physics, nuclear physics, and solid state physics. Assistantships can begin in June, August, or January. Please address your inquiry to Department of Physics and Astronomy, The University of Iowa, Iowa City, IA 52242.

Exploration Geophysics/University of Oklahoma. As part of a 5 year plan of development and expansion, the School of Geology and Geophysics is looking for a person to form the nucleus of an exploration geophysics group. A Ph.D. in geophysics is required, and preference will be given to someone whose teaching and research interests are in the acquisition, processing, and/or interpretation of seismic data. Present equipment includes a truck-mounted thumper energy source, capable of penetrating a kilometer or more of rock, a portable, 12-channel seismic recording system, gravimeters, magnetometers, an electrical resistivity unit, in-house mini computers, and terminals to the University's IBM 370 system. A geophysical observatory supports research in solid earth geophysics, and the exploration geophysicist would work closely with the tectonics-solid earth geophysics group.

Applications are due February 15, 1981. Salary is competitive with industrial standards. Inquiries and applications should be sent to John Wickham, Director, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

The University of Oklahoma does not discriminate on the basis of race or sex and is an equal opportunity employer.

Synoptic/Dynamic Meteorology. Description: The Geophysical Institute and Division of Geosciences, University of Alaska, invite applications from qualified scientists for a full-time (12 month) faculty position at the Assistant or Associate Professor level. The successful candidate will be expected to prepare and submit research proposals to external agencies and to work cooperatively with ongoing research programs. He/she will be also expected to teach occasional courses in synoptic/dynamic meteorology at the upper division and graduate levels.

Qualifications: Ph.D. in meteorology. Research experience in advanced analysis and diagnostic studies of global-scale meteorological processes is essential, preferably over the full height of the atmosphere (0–100 km). Preference will be given to applicants who can utilize their expertise in synoptic/dynamic meteorology to synthesize the results of various ongoing research projects in mesoscale and large-scale meteorology, cloud physics, radiation, aeronomy, and space physics into a better understanding of the large-scale meteorology of the North Pacific and polar regions. Teaching experience at the undergraduate and graduate levels is desirable.

Salary: Upward to $34,800 (Asst. Prof.) or $43,300 (Assoc. Prof.) per year, dependent upon qualifications and experience.

Applications: For further information, including recent annual research report, write to Director, Geophysical Institute, University of Alaska, Fairbanks, AK 99701. Closing date for applications is February 28, 1981.

The University of Alaska is an equal opportunity/affirmative action employer.

Sedimentary Petrologist. The Geology Department at the University of Vermont is seeking a sedimentary petrologist for a tenure track position at the assistant professor level. Research and teaching specializations should be in classic sedimentary petrology with potential ancillary interests in petroleum geology, geomorphology, and hydrology. It is expected that the successful candidate will establish a field-oriented research program which includes supervision of graduate (M.S.) and undergraduate students. A Ph.D. is required and teaching experience is highly desirable. The Geology Department at the University of Vermont is a seven member department having an M.S. program and a definite commitment to excellence in undergraduate education. Applications will be accepted until April 1, 1981.

Candidates should send a resume and arrange for three letters of reference to be sent to

John C. Drake
Acting Chairman
Department of Geology
University of Vermont
Burlington, Vermont 05405

The University of Vermont is an equal opportunity/affirmative action employer.

Faculty Position. The Department of Geology of the University of New Mexico seeks applicants for a position in clay mineralogy, low-temperature geochemistry, carbonate petrology, or economic geology. The appointment may be at the assistant, associate or full professor level contingent on approval of funding from the university. The individual must be strongly committed to teaching at both the undergraduate and graduate levels. In addition, he or she will be expected to develop a vigorous research program in his or her field of specialty and will be expected to supervise graduate students at the M.S. and Ph.D. levels. The closing date for application is April 15, 1981. Applicants should send a résumé, undergraduate and graduate transcripts, three letters of reference, and a brief discussion of research interests to Rodney C. Ewing, Chairman, Department of Geology, University of New Mexico, 87131.

The University of New Mexico is an equal opportunity/affirmative action employer.

Geophysics Research Associate. Weston Observatory of Boston College seeks MS in geophysics (doctorate work desirable), familiarity with time and frequency domain analytical techniques and knowledge of FORTRAN programming. Opportunity for independent research along with assigned responsibilities relating to New England seismic network. Salary to $20,000 depending on qualifications and excellent benefits. Send letter and resume to Dianne Rogers, Associate Director of Personnel, Boston College, 140 Commonwealth Avenue, Chestnut Hill, MA 02167.

An equal opportunity/affirmative action employer.

Drexel University/Atmospheric Scientist. Three tenure track faculty positions are anticipated starting fall 1981. Applications are solicited from Ph.D.s with independent research experience in one of the following areas of atmospheric science: general circulation; climate dynamics with application in satellite meteorology; atmospheric optics, experimental or theoretical with emphasis in mesoscale probing; boundary layer turbulence modeling and atmospheric chemistry modeling. Rank and salary commensurate with experience. Send resume and references to Dr. William W. Erdson, Head, Department of Physics and Atmospheric Science, Drexel University, Philadelphia, PA 19104.

An equal opportunity/affirmative action employer.

Program Manager/Meteorology. Oceanographic Services, Inc., is seeking qualified applicants for the position of program manager for meteorological studies. Applicants should have an M.S. or Ph.D. in meteorology or atmospheric sciences, plus experience in the field. A broad general knowledge of air pollution, and an understanding of the air pollution regulatory environment, is helpful. Interested persons should send resume, references, and salary history to R. C. Banks, Oceanographic Services, Inc., 25 Castilian Drive, Goleta, CA 93117.

Research Plasma Physicist. Berkeley Scholars, Inc. has opening in D.C. area. Must be eligible for Ph.D. in plasma physics with specialization in and abstracts presented on theory and numerical simulation of magnetic shear effects on instability phenomena as applied to ionospheric and magnetospheric problems. 1 yr. work experience in the field is required. Salary is $20,000 per yr., 40 hrs. per wk. Send resume directly to Berkeley Scholars, Inc., P.O. Box 983, Berkeley, CA 94701.

An AA/EOE.

RESEARCH OCEANOGRAPHER

The Radar and Optics Division of ERIM requires a Radar Oceanographer, preferably at the PhD level, to function as head of the Oceanographic Measurements and Analysis Group of the EM Measurements Department. Experience as an Oceanographer including EM measurements of oceanographic phenomena is required. Experience in the management of research programs is desirable. Candidates should have knowledge of EM remote sensor systems and techniques. The EM Measurements Department conducts research programs to apply EM measurements techniques to oceanographic problems.

ERIM, a non-profit corporation, is a center of research and development on sophisticated sensors and data processing techniques used by the Department of Defense and other agencies engaged in remote sensing.

ERIM is located adjacent to the campus of The University of Michigan in Ann Arbor. The Ann Arbor area has exceptional academic, cultural, entertainment and recreational opportunities.

Send your resumé and salary requirements in confidence to John J. Malik. U.S. citizenship is required.

ERIM
P.O. Box 8618
Ann Arbor, Michigan 48107

An equal opportunity employer.

Queens College. Position for 1-2 years as sabbatical replacement starts September 1981. Specialties requested: geochemistry (organic, environmental, or exploration); exploration geophysics; groundwater geology. A Ph.D. required. Applications should include c.v. and three references. Send to D. H. Speidel, Department of Earth and Environmental Sciences, Flushing, NY 11367.

Queens College is an affirmative action/equal opportunity employer.

Geophysicist/University of South Carolina. The University of South Carolina anticipates a new faculty appointment in geophysics for 1981, subject to adequate legislative funding. We are especially interested in individuals who have expertise in the fields of exploration geophysics, seismic interpretation, or solid earth geophysics. This would be a 9-month, tenure track position at the assistant or associate professor level, beginning August 1981. Some start-up funds are available for major equipment purchases. The individual who fills this position would join the growing geophysical component of the Geology Department, which currently emphasizes seismology, regional tectonics, and paleomagnetics, and would develop an aggressive research program in his or her specialty.

Please send vitae and names and phone numbers of three individuals we may contact for references to Willard S. Moore, Chairman, Search Committee for Geophysics, University of South Carolina, Columbia, SC 29208. Closing date for this announcement is March 15, 1981.

The University of South Carolina is an affirmative action/equal opportunity employer.

Scientists/Meteorologists/Engineers. Science Systems and Applications, Inc., (SSAI) has positions for programmers, analysts, scientists and engineers to engage in scientific modeling and data analysis activities in the areas of: 1. Plasma/ionospheric physics theoretical simulations 2. Atmospheric/oceanic sciences 3. Remote sensing & radiative transfer/scattering studies 4. Satellite data analysis 5. Weather/climate & severe storms studies 6. Atmospheric/fluid dynamics 7. Solar and planetary physics and astronomy 8. Computer image processing and systems displays 9. System software/hardware engineering 10. Nuclear fusion/fission and 11. Applied mathematics. These positions involve working with NASA/NOAA/NAVY scientists in metropolitan, Washington, D.C. area. A strong background in numerical simulations, and experience in working with large scale computers is required for entry level to senior scientist/engineer positions. SSAI provides a congenial academic environment, pays liberal fringe benefits and awards bonuses to its employees. Please send your resume with salary history and references to Science Systems and Applications Inc., The Aerospace Building, Suite 140, 10210 Greenbelt Road, Seabrook, MD 20801.

AGU

Stephen J. Burges—New WRR Editor

The 'tower of Babel syndrome' is the most important problem facing water-resources researchers, says Stephen J. Burges, the new coeditor for hydrology and physical, chemical, and biological sciences for *Water Resources Research* (WRR). Burges was appointed to a 4-year term which began November 1. He succeeds R. Allan Freeze.

Specialized research that lacks a sense of connection to other aspects of hydrology characterizes the syndrome, Burges explained. He traces this scattering of interests back to 1966 with the 'evolution' of the third-generation computer.

To help add coherence to WRR's coverage of hydrology, Burges plans some changes. With the addition of four associate editors, the breadth of topics will be increased to include ecological modeling, sediments, and precipitation. In addition, Burges will ask authors to explain in a paragraph at the beginning of their papers how the research relates to other water-resources problems. Authors also will be requested to identify the status of research described in the paper, and to state clearly whose work or computer models the research uses.

Burges said that he and coeditor Jared Cohon hope to achieve a better balance of topics and to increase readership with these changes.

Under Burges, the associate editors will continue to play a major role in choosing reviewers and in maintaining the high standards of WRR; the basic management style used by Freeze has been found to be effective. In addition, Burges plans to continue to solicit appropriate review articles to add balance to WRR. Freeze initiated solicitation of these articles; Burges and Cohon plan to coordinate their selection of review topics to bring the two major divisions of WRR closer together.

Following completion of his Ph.D. in civil engineering at Stanford, Burges joined the University of Washington faculty in 1970. His undergraduate degrees (physics, mathematics, and civil engineering) were taken at the University of Newcastle, Australia. His research and teaching have focused on the application of systematic approaches to analysis and design of water-resources systems, with an emphasis on stochastic hydrology.

'At heart I'm a civil engineer,' Burges said. 'I also like using a systematic approach to problem solving.' Surface water-

storage reservoirs dominate his interests. He said that he's also intrigued by urban water problems, including large-scale systems and flood/drought research. He views stochastic hydrology as an essential tool for the future. 'We need a method to determine reliability of water systems.'

Burges said he looks forward to working closely with Cohon and maintaining the high standards set by previous editors. Burges noted that they are indebted to Freeze for his outstanding editorial leadership and want to thank him publicly.

Meetings

Recent Earthquakes Symposium

A call for papers for the symposium 'Reports of Recent Earthquakes' has been made by Ziro Suzuki, second vice president of IASPEI. The symposium will be held July 22, as a part of IASPEI's 21st General Assembly, at the University of Western Ontario in London, Ontario.

Abstract forms are available from Suzuki at the Geophysical Institute, Tohoku University, Sendai 980, Japan. Requests for the forms should include author name and address, tentative paper title, and name, place, and time of the earthquake to be reported. Completed abstract forms should be mailed by March 1 to A. E. Beck, Department of Geophysics, University of Western Ontario, London, Ontario N6A 5B7, Canada. A copy should be sent to Suzuki. Some deadline flexibility will be allowed, but authors should receive permission from the committee. Papers on earthquakes that occurred during the second half of 1980 can be accepted after March 1.

Time restricts the number of papers on each earthquake to two. Review papers rather than personal studies are preferred.

European Geophysical Meeting

A call for papers has been issued for the Eighth Annual European Geophysical Society Meeting, scheduled for August 24–29 in Uppsala, Sweden. Abstracts—one original and two copies—should be sent to K. M. Storetvedt, Chairman Program Committee, Institute of Geophysics, University of Bergen, Allégt. 70, N-5014 Bergen University, Norway. Deadline for receipt of abstracts is June 1.

In addition to 13 symposia, one workshop, and an excursion to a meteor-impact structure, there will be two society lectures. H. Alfvén of Stockholm will speak on plasmas in the cosmos and the laboratory, and H. Moritz of Graz will give a lecture entitled 'The Figure of the Earth.'

Applications for travel awards for young scientists are due March 31. Forms can be obtained from the EGS General Secretary, 6 Carlton House Terrace, London SW1Y 5AG.

More information about the meeting, which will run simultaneously with the Uppsala Caledonide Symposium, can be provided by the Local Organizing Committee, C.-E. Lund, Chairman, Box 556, S-75122, Uppsala, Sweden.

Hydrometeorology Session

The 15th Annual Congress and Annual Meeting of the Canadian Meteorological and Oceanographic Society (CMOS) will be held at the University of Saskatchewan, Saskatoon, Saskatchewan, on May 27–29. The focus of the Congress will be hydrometeorology; scheduled are sessions on waves and tides, drought management, the Canadian Climate Program, environmental assessment, stratospheric dynamics, remote sensing, and polluted precipitation. In addition, sessions on air-pollution meteorology, sponsored by a CMOS special interest group, will be conducted concurrently.

Authors wishing to present papers at the congress or at the special air-pollution sessions should submit abstracts of fewer than 300 words by February 1. Address all correspondence to Barry Goodison, Hydrometeorology Division, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 (call 416-667-4914). Authors should indicate in which session they wish to be included.

California Mining Association

California's minerals industry and its impact on the nation will be the focus of the 1981 California Mining Association Annual Meeting in San Diego, March 5–7.

Technical aspects of California mining and political problems which concern the industry will be emphasized. More than 200 representatives from major industrial mining firms in the state are expected to attend.

Registration is $75 per person; spouse registration is free. For additional information contact the association at P.O. Box 3, Jackson, California 95642, or call (209) 223-1129.

Geodetic Networks and Computations

An international symposium on geodetic networks and computations will be held in Munich, August 31 to September 5. The symposium, sponsored by the International Association of Geodesy, will take place at the Bavarian Academy of Sciences.

Topics to be covered at the symposium include objectives of geodetic networks, status reports, and future plans; optimal design of geodetic networks; network analysis models; space techniques for terrestrial networks; combination of horizontal, vertical, and gravity networks; and computational problems in classical and nonclassical adjustment models.

For additional information and registration forms, write to Deutsche Geodätische Kommission, Bayerischen Akademie der Wissenschaften, Marstallplatz 8, D-8000 München 22.

Snow Chemistry: Call for Papers

A call for papers has been issued for the 38th Eastern Snow Conference, scheduled for June 4–5 in Syracuse, New York. A special session will be held on snowpack and snowfall chemistry.

Authors wishing to present a paper should submit an abstract before February 15 to Barry E. Goodison, Program Chairman, Hydrometeorology Division, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4, Canada (call 416-667-4914).

IASPEI Workshop: Seismic Modeling of Laterally Varying Structures

During the past 10 years, significant progress has been made in the methods of collection and analysis of seismic reflection and refraction data. This progress has led to the development of new models for the structure and composition of the earth's crust, based on sophisticated analysis of numerous profiles in many areas of geologic importance. The third triannual meeting of the IASPEI (International Association of Seismology and Physics of the Earth's Interior) Commission of Controlled Source Seismology was convened in Park City, Utah, on August 11–17, 1980, to bring together seismologists and geologists to explore and assess the progress of controlled source techniques (controlled sources include explosions, air guns, and Vibroseis-type sources), and to evaluate its significance in terms of current models of the seismic velocity structure and composition of the crust and upper mantle. Particular attention was paid to the progress and problems in the modeling of two- and three-dimensional structures.

The Park City location of the conference was ideal for the contemplation of the complex structures that we are presently attempting to model. The effects on the crust of the action of tectonic forces were easily discernible from the air during the approach to the Salt Lake City airport, and on the ground during the field trip into the Wasatch Mountains led by R. B. Smith of the University of Utah.

Two and one half days of the 5-day conference were used to discuss different interpretations of the seismic refraction data collected in Saudi Arabia by the U.S. Geological Survey in 1978 [*Blank et al.*, 1979; *Lamson and Leone*, 1979]. The format of this portion of the meeting was unlike most other scientific workshops. The complete refraction data set had been distributed to the participants well in advance of the meeting, giving each seismologist (or team of seismologists) time to thoughtfully analyze the same data. The use of a common data base allowed for a kind of in-depth examination of issues of interpretation that is not possible in traditional workshops which are based on diverse data sets.

A discussion of the geologic framework of Saudi Arabia and the southeastern Red Sea was particularly pertinent because all proper seismic interpretations are constrained by the known surface geology. (The geologic map of Saudi Arabia was distributed to all participants along with the seismic data set.) The discussions began with an introduction to the geologic problems of Saudi Arabia by H. R. Blank and an outline of the planning and goals of the 900-km-long refraction profile (see the figure, part A) by M. Q. Assad. This was followed by a series of speakers who explained their team's interpretation of the data and the methods that they used to derive velocity-depth structures. In the course of these presentations it became evident that the main source of differences in the final models is the phase correlation of the data. The term 'phase correlation' refers to the process of identifying, within a seismic record section, those arrivals which refract or reflect from the same feature (or portion) of the crustal or mantle velocity structure. For example, the phase P^* refracts in the middle crust, while PmP reflects from the M discontinuity. A knowledge of the expected amplitude and frequency of a particular phase, based on experience and theoretical considerations, facilitates its correlation in the record section, but the complexity of the typically observed wave field leads to a degree of subjectivity in the interpretation of the phases. Given identical phase correlations, different methods of travel time and amplitude analysis of these phases will produce nearly the same result. Conversely, different correlations will result in markedly divergent models. These points can be appreciated from the comparison of the models of the Arabian shield (see figure, part B) to those of the Red Sea-continent transition (see figure, part C). For the most part, the teams of interpreters agreed on the phase correlation of the profiles between shot points 1 and 5 (see figure), and the resultant models reflect this agreement. However, the correlations and interpretations of the data crossing the Red Sea-continent transition were diverse, which ultimately led to quite different models for that region (see figure, part C).

A few highlights of the meeting on the interpretation of the Saudi Arabian refraction data are summarized below. These few impressions do not completely characterize the great amount of interpretive skill brought to bear on the data and the lively and constructive discussion that ensued.

(1) The upper crust (21 km thick) of the shield has a near-surface velocity of 6.1 km/s and, in most regions, a positive velocity gradient of 0.01–0.02 km/s/km. Low velocity zones may be present in some regions.

(2) The lower crust (19 km thick) of the shield is separated from the upper crust by a seismic discontinuity or smooth transition of 0.2–0.4 km/s. The average velocity of the lower crust is about 6.7 km/s.

(3) The M discontinuity is probably a transition zone 2–5 km thick and occurs at a nearly constant depth of about 40 km. Uppermost mantle velocity is 8.0–8.1 km/s, and there is evidence for fine structure within the lithosphere.

(4) The structure of the Red Sea-continent transition remains uncertain with the currently available data. The range of proposed models is indicated in the figure, part C. Improved models would result from the recommendations below.

A general consensus was reached on recommendations for future seismic refraction and reflection work in areas with strong lateral velocity heterogeneous structure, such as the Red Sea-continent transition in western Saudi Arabia:

(1) Parallel-to-structure refraction profiles are needed in regions of complex structure. In the present case, refraction profiles are needed along the coastal plain and in the Red Sea.

(2) Perpendicular-to-structure profiles must be densely recorded and should include considerable data redundancy.

(3) Critically placed seismic reflection profiles would help resolve details in the areas of greatest structural complexity. In the present case, reflection profiles crossing the Hijaz Azir Escarpment (see figure, part A) would help in understanding the structure across this rift boundary.

The commission officers were (chairman) S. Mueller, ETH-Zurich, Switzerland, and (secretary) J. Ansorge, ETH-Zurich, Switzerland. The local organizers were D. P. Hill, Menlo Park, California; J. A. Orcutt, La Jolla, California; and R. B. Smith, Salt Lake City, Utah.

Acknowledgments

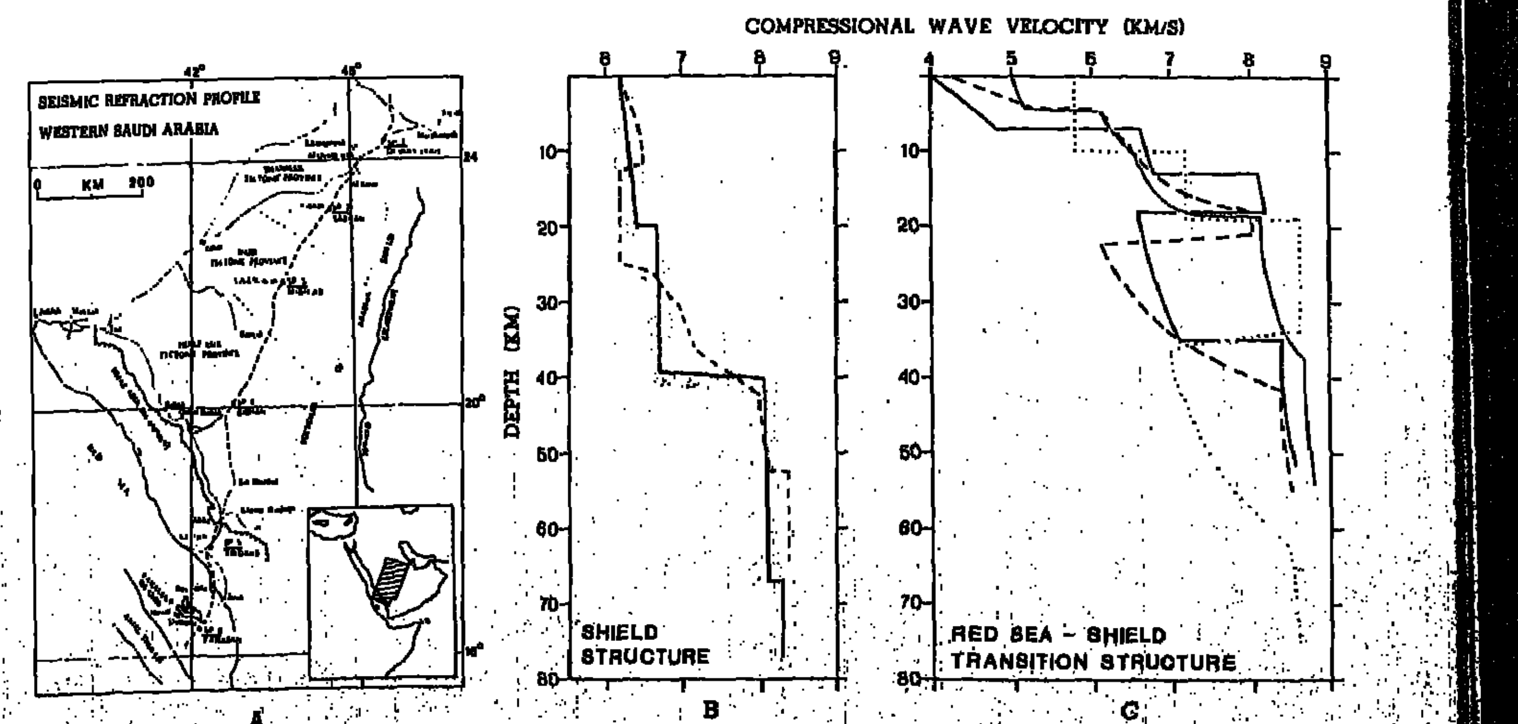
Financial support for the workshop was provided by the Office of Naval Research and the U.S. Geological Survey. We thank the Directorate General of Mineral Resources, Saudi Arabia, for permission to use the seismic refraction data for this workshop.

References

Blank, H. R., J. H. Healy, J. Roller, R. Lamson, F. Fisher, R. McClearn, and S. Allen, Seismic refraction profile, Kingdom of Saudi Arabia: Field operations, instrumentation, and initial results, *Rep. 259*, 49 pp., Saudi Arabian Mission Proj., U.S. Geol. Surv., Menlo Park, Calif., 1979.

Lamson, R., and L. Leone, Saudi Arabia seismic refraction profile: Data set, Volume I and II, *Geol. Surv. Open File Rep. (U.S.) 79-1601*, 1980.

This meeting report was prepared by Walter D. Mooney, USGS, Menlo Park, California.



(A) Location map, USGS-conducted seismic refraction investigation of western Saudi Arabia and the southeastern Red Sea: shot points (SP), profile line (dashed line), and tectonic provinces. (B) P wave velocity structure of the Arabian Shield, presented by workshop participants; shaded region outlines the range of velocities of most models; solid line is a typical example, while dashed line is an alternative model. (C) Four P wave velocity structures for the Red Sea-Shield transition: the data were sparse in this laterally inhomogeneous region, making possible these radically different interpretations.

Baltimore
AGU Spring Meeting
May 25-29

Call for Papers

Abstracts must be received at the AGU office by 5 P.M. on March 4 to be on time. Late abstracts (1) may be summarily rejected by program chairman, (2) may not be published in advance of the meeting, and (3) if accepted, will be charged a $25 late fee in addition to the regular publication charge.

General Regulations

Abstracts may be rejected without consideration of their content if they have not been received by the deadline or are not in the proper format. Abstracts may also be rejected if they contain material outside the scope of AGU activities or because they contain material already published or presented elsewhere. ONLY ONE CONTRIBUTED PAPER BY THE SAME FIRST AUTHOR WILL BE CONSIDERED for presentation; additional papers (unless invited) will be automatically rejected.

Only AGU members may submit an abstract. The abstract of a nonmember must be accompanied by a membership application form (with payment), or it must be sponsored by an AGU member.

A publication charge of $40.00 for each contributed abstract will be invoiced ($20.00 if the first author is a student member and if the appropriate notation is made on the abstract when submitted.) Both invited and contributed papers are subject to the publication charge unless specifically waived in writing. To repeat, the abstract must be received at AGU by March 4 to avoid an additional $25.00 charge. If a revised version of an abstract must be published, it will also be assessed a $25.00 charge.

Authors will be notified by mail in late April of the status of their papers. Receipt of all papers will be acknowledged.

Ten minutes is normally allowed for the presentation of each contributed paper, and only 2" × 2" (35-mm) slide projectors and viewgraphs are usually available as standard equipment at the meeting. All other equipment is available at cost plus a $10.00 billing charge if we have to invoice.

Instructions for Preparing Meeting Abstracts

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Geodesy
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Hydrology
John Ferris Symposium on Groundwater Hydraulics
Water Policies and Ground Water
Symposium on the EPA-USGS National Urban Runoff Program
Trace Organics in Groundwater
Public Water Supply
What Geochemistry Can Tell Us About Background Water Quality
The Efficacy of Modelling in Water Resources Planning and Management
Acid Rain: Assessment and Impact
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Desertification: Imagined or Real?

Planetology
Geological Processes on Icy Bodies

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New Frontiers in Earth Structure: Anisotropy, Scattering, and Q.
Reflection and Refraction Seismology: Theory and Observation

SPR-Cosmic Rays & SPR-Solar and Interplanetary Physics
Solar Flare Particle Acceleration
Solar Flare Particle Composition

SPR-Magnetospheric Physics
Waves, Instabilities and Turbulence in Space Plasmas (POSTER SESSION).

Tectonophysics
Tectonics of Venus and Earth: A Comparison (cosponsor: Planetology and Geodesy).
Large-Scale Thin-Skin Tectonics (cosponsor: Seismology).
Illinois Deep Hole Project

Volcanology, Geochemistry, and Petrology
Silicate Melt Structure and Processes of Crystallization in Igneous Rocks
Precambrian Evolution of the Earth (cosponsor: Planetology and Tectonophysics).
SEASAT (cosponsors: Oceanography, Meteorology, and Geodesy).

GAP

Electromagnetics

0760 Plasmas
ON THE PARAMETRIC DEPENDENCES OF THE BEAM-PLASMA-DISCHARGE AT LOW PRESSURES AND MAGNETIC FIELD STRENGTHS
S. Cuperman (NOAA/ERL/SEL/ Boulder, Colorado 80303 USA and Department of Physics and Astronomy, Tel-Aviv University, Ramat-Aviv, Israel) I. Roth (Department of Physics and Astronomy, Tel-Aviv University, Ramat-Aviv, Israel)

An explanation for the relationship between the critical current and the physical parameters observed in recent experiments on beam-plasma-discharge at low pressures and magnetic fields is proposed. The observed relationship is reproduced by combining the threshold condition for electrostatic instability in a magnetized, bounded beam-plasma system and the balance equation for the rate of plasma production and that of loss through the ends. It is found that the principal scaling of the threshold criterion with variations in the magnetic field is determined by the variations in the radius of the beam-plasma system.
Geophys. Res. Lett., Paper 80L1572

0790 Instrumentation and techniques
LASERS AND LEDs FOR OPTICAL COMMUNICATIONS USING FIBERS
H. Kressel (RCA Laboratories, Princeton, New Jersey 08540)

Laser diodes and light emitting diodes suitable for optical communication systems have reached a stage of maturity which makes their practical use possible. Of the two spectral regions of interest, 0.8 to 0.9 μm and 1.1 to 1.7 μm, the first is the most widely used because the AlGaAs double heterojunction devices are the most developed. However, rapid progress is being made in the development of the longer wavelength InGaAsP/InP devices. Laser research and development is currently also focused on devices operating reliably in the fundamental spatial mode in order to insure kink-free operation and a single beam far field. Several structures have been developed which meet the objective of fundamental spatial mode operation at power levels (cw) on the order of 10 mW.
Rad. Sci. Paper 8031789

Geodesy and Gravity

1930 High order harmonics of the gravity potential field and local gravity anomalies
THE GRAVITY FIELD IN THE CENTRAL PACIFIC FROM SATELLITE-TO-SATELLITE TRACKING
James G. Marsh (Earth Survey Applications Division Goddard Space Flight Center, Greenbelt, Maryland 20771) Bruce D. Marsh, Ronald G. Williamson and William T. Wells

Satellite-to-satellite Doppler tracking between the ATS-6 and the GEOS-3 spacecraft is used to measure the high degree and order gravity field over an 80° area in the central Pacific Ocean. Doppler tracking provides velocity measurements of GEOS-3 as a function of time which are easily converted to line-of-sight accelerations. Since the low degree and order gravity field is known well, each GEOS-3 revolution is reduced relative to a twelfth degree and order field model. The method is then capable of measuring wavelengths in the range of from about 3500 to 1000 km. Accelerations computed along forty revolutions, roughly half of them descending and the others ascending, can be contoured into a map of the gravity field at the GEOS-3 altitude of 840 km. The dominant wavelength of the map is about 2000 km. A comparison of this field with an altimeter-derived geoid and the GEM-10B gravity field shows good agreement. Since each map is essentially independent of the others, this comparison is critical in establishing the validity of any of the maps. Each map shows virtually the same areas of positive and negative anomaly. These areas are essentially the same in the central Pacific as found in our earlier study. Compared with surface amplitudes these anomalies are only one-tenth as large at the GEOS-3 altitude. This observation and the correlation of gravity with residual depth anomalies implies that the cause of some of these anomalies may be due to bumps in the upper surface of the lithosphere that are compensated at depths of about 50-100 km. Some of the anomalies apparently do not correlate with residual depth anomalies.
J. Geophys. Res., Red, Paper 8031830

1950 Relations of gravity observations to tectonics and isostasy
A MARINE GEOPHYSICAL STUDY OF THE "COMORIN RIDGE", NORTH CENTRAL INDIAN BASIN
H.-G. Kahle (Institut für Geodäsie und Photogrammetrie, ETH-Hönggerberg, 8093 Zürich, Switzerland) B.H. Naini, M. Talwani and O. Eldholm

Marine geophysical data are used to interpret the continental margin ... parallel to the southwest coast of India. This line marks the eastern boundary of a topographic and basement high here named the "Comorin Ridge" which is also clearly seen on a sediment isopach map. The ridge seems to act as a barrier to the passage of Ganges Cone sediments to the west. A comparison of the eastern (landward) edge of the Comorin Ridge with similar structures of other passive continental margins such as those off southern South Africa (Agulhas Fracture zone), off the Falkland Plateau and off western Norway is made. It is suggested that the eastern edge of the Comorin Ridge may mark a significant structural crustal boundary. (Marine geophysics, free-air and isostatic anomalies, continental margin structure).
J. Geophys. Res., Red, Paper 8081828

Geomagnetism and Paleomagnetism

2560 Time variations, paleomagnetism
PALEOMAGNETISM OF THE ROSKRUGE AND GRINGO GULCH VOLCANICS, SOUTHEAST ARIZONA
Rob Van der Voo, Arthur L. Barnes, and Robert F. Butler (Department of Geosciences, University of Arizona, Tucson, Arizona 85721)

Paleomagnetic data were obtained from nine cooling units of the late Cretaceous (~72 Ma) Roskruge Volcanics and from twenty-five flows in the lower Paleocene Gringo Gulch Volcanics, both from southeastern Arizona. Alternating field demagnetization successfully erased the infrequent secondary components of magnetization. The paleomagnetic pole position obtained from the Roskruge Volcanics is at 73.6°N, 176.0°E with dp = 6.2° and dm = 8.8°. The Gringo Gulch Volcanics pole position is at 77.0°N, 201.0°E with dp = 1.2° and dm = 1.7°. In conjunction with other recently published Paleocene and Eocene paleomagnetic poles, these data provide details of North American apparent polar wander during the Laramide orogeny (~80 Ma to ~40 Ma). An episode of rapid apparent polar wander from the Cretaceous pole position in the Bering Strait to the Eocene pole position near the present rotation axis occurred during that interval of time. The initiation of this episode of apparent polar wander appears to be coincident with the major plate reorganizations which occurred at the onset of the Laramide orogeny. (Paleomagnetism, apparent polar wander, Cretaceous, Paleocene, North America.)
J. Geophys. Res., Red, Paper 8081826

2560 Time variations, paleomagnetism
ANALYSIS OF THE MULTICOMPONENT MAGNETIZATION OF THE LITTLE DAL GROUP, MACKENZIE MOUNTAINS, NORTHWEST TERRITORIES, CANADA
J.K. Park (Geomagnetic Lab., Earth Physics Branch, Dept. of Energy, Mines, and Resources, Ottawa, Ontario, Canada K1A 0Y3)

A paleomagnetic study on 14 red limestone sites of the Helikian Little Dal Group, 'basinal sequence' (Mackenzie Mountains, Northwest Territories, Canada) resolved five magnetizations using thermal and alternating field treatment with vector analysis. One magnetization ($\underline{C}$) with low unblocking temperatures (<350°C) is probably a goethite weathering component of Cretaceous age. It gives a direction at 291°,+75° (12 sites, $\underline{k}$=73, α_{95}=5°) and a pole at 60°N, 170°E. Two other closely related magnetizations ($\underline{A}$, detrital?) probably carried by magnetite ($\underline{A}_M$) and hematite ($\underline{A}_H$) respectively, yield directions of 265°,-29° ($\underline{k}$=87, α_{95}=4°) and 264°,-26° ($\underline{k}$=53, α_{95}=6°) with a combined pole at 16°S,141°E (14 sites, $\underline{K}$=141, A_{95}=3°). The two remaining magnetizations ($\underline{B}$, red hematite pigment?) — a normal ($\underline{B}_N$) and a reverse ($\underline{B}_R$) component recognized in most specimens — have a combined direction of 273°,-09° ($\underline{k}$=17, α_{95}=10°) and a pole at 3°S,138°E (13 sites, $\underline{K}$=26, A_{95}=8°). $\underline{C}$ and $\underline{A}$ are prefolding (before Paleocene or pre-late Cretaceous) with $\underline{A}$ suggested to be primary. $\underline{A}$ and $\underline{B}$ lie close to a recently proposed polar track for the late Helikian and Hadrynian and evidence suggests a magnetization age for $\underline{A}$ of 900 to 950 Ma. (Paleomagnetism, magnetization, multicomponents, Precambrian).
J. Geophys. Res., Red, Paper 8081827

Hydrology

3130 Groundwater
A STUDY OF REGIONAL TEMPERATURE AND THERMOHYDROLOGIC EFFECTS OF AN UNDERGROUND REPOSITORY FOR NUCLEAR WASTES IN HARD ROCK
J.S.Y. Wang (Earth Sciences Division, Lawrence Berkeley Laboratory, University of California, Berkeley, California 94720), C.F. Tsang, N.G.W. Cook and P.A. Witherspoon

Heat released by the radioactive decay of nuclear wastes in an underground repository causes a long-term thermal disturbance in the rock mass. The nature of this disturbance for a planar repository 3000 m in diameter at a depth of 500 m below surface is investigated. Loaded initially with a power density of 10 W/m² of spent fuel assemblies 10 years after discharge from a reactor, the maximum increase in temperature of the repository in granite is about 50°C and the epicentral thermal gradient about 70°C/km. Different waste forms and periods before burial have significant effects on the thermal disturbance. The effects of temperature changes on the groundwater flow are evaluated with simple models of a vertical fracture connected to a horizontal fracture in the rock mass. The buoyancy groundwater flow through the vertical fracture is a function of both the vertical and the horizontal fracture transmissivities, as well as the changes in density and viscosity of groundwater caused by the temperature changes. Finite hydraulic recharge from surrounding rock mass affects the thermohydrologic disturbance. (Radioactive waste repository, fracture flow, buoyancy flow, temperature).
J. Geophys. Res., Red, Paper 8081825

Meteorology

3715 Chemical composition and chemical interactions
MEASUREMENTS OF STRATOSPHERIC SULFATE MIXING RATIO WITH A MULTI FILTER SAMPLER
B. W. Gandrud and A. L. Lazrus (National Center For Atmospheric Research, P. O. Box 3000, Boulder, Colorado 80307)

A new multi filter sampler (MFS) was used to measure daily profiles of sulfate aerosol in Alaska during the period July 16 through July 19, 1979. During these 4 days, the variability in each that the percent standard deviation of an individual profile from the mean is as high as 21%. The results of these flights are compared with the Project Airstream results from the same time period.
Geophys. Res. Lett., Paper 80L1775

3715 Chemical composition and chemical interactions
ATMOSPHERIC MEASUREMENTS OF CF_4 AND OTHER FLUOROCARBONS CONTAINING THE CF_3 GROUPING
S.A. Penkett (A.E.R.E. Harwell, England) N.J.D. Prosser, R.A. Rasmussen and M.A.K. Khalil

Careful measurements by GC/MS techniques on atmospheric carbon tetrafluoride confirm that its concentration in 1979 was constant at about 69.9 pptv (standard deviation = 7.2 pptv). It is almost certainly produced entirely by emissions from the aluminium industry.

Other compounds in the atmosphere containing the CF_3 group have been identified by GC/MS as C_2F_6, CF_3Cl, CF_3Br and C_2F_5Cl. The concentrations of the first pair are about 4 pptv and the latter two are about 0.7 pptv and 4 pptv respectively. The C_2F_6 is produced simultaneously with CF_4 in the manufacture of aluminium. CF_3Cl, CF_3Br and C_2F_5Cl are probably produced by the chemical industry.

The environmental importance of these compounds is discussed in the context of two papers recently published on CF_4 by Cicerone (1979) and by Wang et al. (1980). (Fluorocarbons, aluminium industry, greenhouse effects).
J. Geophys. Res., Green, Paper 80C1760

3720 Climatology
RADIATIVE PROPERTIES OF THE BACKGROUND STRATOSPHERIC AEROSOLS AND IMPLICATIONS FOR PERTURBED CONDITIONS
James B. Pollack and Owen B. Toon (Space Science Division, Ames Research Center NASA, Moffett Field, California 94035) Donald Wiedman ...

We have carried out a series of ... the wavelength dependence ... in the stratosphere ... particles were ... radiation budget ... measurements ... from aircraft ... too small for ... optical depth ... during some ... caused a noticeable ... troposphere ...
Geophys. Res. Lett., Paper 80L1777

3760 Ionic interactions and processes
NEGATIVE ION COMPOSITION MEASUREMENTS IN THE STRATOSPHERE
E. Arijs, D. Nevejans, P. Frederick and J. Ingels (Belgian Institute for Space Aeronomy, Ringlaan 3, B-1180 Brussels, Belgium)

Composition measurements of negative ions in the stratosphere were performed at altitudes over 35 km by means of a balloon borne mass spectrometer during a recent balloon flight. The observed ions were identified as mixed cluster ions of the form $HSO_4^-(HNO_3)$ and $HSO_4^-(H_2SO_4)_m(H_2O)_n$. Hydrated clusters of both ion families have also been detected. A reaction scheme is proposed to explain the data. The relative abundances of the ion mass peaks is used to derive the number density of nitric acid and sulfuric acid in the gas phase.
Geophys. Res. Lett., Paper 80L1779

3770 Particles and aerosols
LIDAR DETECTION OF STRATOSPHERIC AEROSOL IN ITALY AFTER ST. HELENS ERUPTION
A. D'Altorio, F. Masci, G. Visconti (Istituto di Fisica, Università dell'Aquila, 67100 L'Aquila, Italy) and G. Fiocco

We report lidar measurements of the aerosol content of the atmosphere for the first two months following the volcanic explosion of Mt. St. Helens. The measurements were taken over L'Aquila (Italy) with a lidar system. The measurements are compared to similar data for the previous quiescent period and show a large increase of the backscattering ratio in the stratosphere and upper troposphere. Layers have been observed at various altitudes. A strong layer at ... has been observed only initially. Layers between 15-25 km have been observed continually. These features show a considerable day to day variability. (Stratospheric aerosols, volcanic eruption, lidar system).
Geophys. Res. Lett., Paper 80L1482

3770 Particles and aerosols
IN-SITU MEASUREMENTS OF SCATTERING PHASE FUNCTIONS OF STRATOSPHERIC AEROSOL PARTICLES IN ALASKA DURING JULY 1979
G. W. Grams (School of Geophysical Sciences, Georgia Institute of Technology, Atlanta Georgia 30332)

A laser nephelometer developed for airborne measurements of polar scattering diagrams of atmospheric aerosols was flown on the NCAR Sabreliner aircraft to obtain data on light scattering parameters for stratospheric aerosol particles over Alaska during July 1979. Observed values of the angular variation of scattered-light intensity were compared with those calculated for different values of the asymmetry parameter g in the Henyey-Greenstein phase function. Our observations indicate that, for the time and location of the experiments, the Henyey-Greenstein phase function could be used to calculate polar scattering diagrams to within experimental errors for an asymmetry parameter value of g = 0.49 ± 0.07.
Geophys. Res. Lett., Paper 80L1765

3770 Particles and aerosols
IMPLICATIONS OF STRATOSPHERIC AEROSOL MEASUREMENTS FOR MODELS OF AEROSOL FORMATION AND EVOLUTION
...
Geophys. Res. Lett., Paper 80L...2

3770 Particles and aerosols
COMPARISON OF SOLAR ... STRATOSPHERIC AEROSOL MEASUREMENTS ... ALASKA, JULY 1979
...
Geophys. Res. Lett., Paper 80L1764

3770 Particles and aerosols
A STUDY OF STRATOSPHERIC AEROSOL MATURITY
...
Geophys. Res. Lett., Paper 80L1763

Oceanography

4760 Sea Ice
PLANE WAVES IN A VISCOELASTIC FLOATING ICE SHEET
Ernest F. Bates (Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701) L. H. Shapiro

The Correspondence Principle of Viscoelasticity is applied to obtain the plane-wave impulse response of a laterally compressed viscoelastic plate floating on a perfect liquid. The system is analyzed as a wave guide having a small damping factor. A four-parameter linear viscoelastic model is used to simulate the characteristics of a sheet of floating ice. Values appropriate for small deflections in sea ice are used to produce illustrative examples of the displacement and the vertical loading stress caused by the bending produced in an ice sheet by plane waves arising from a unit line force moving uniformly across the sheet. Because the displacement of the viscoelastic plate remains finite, this technique provides a means for making engineering estimates of the stress produced by waves at the critical frequency.
J. Geophys. Res., Green, Paper [illegible]

Particles and Fields—Ionosphere

Particles and Fields—Magnetosphere

Physical Properties of Rocks

... be consistent with theories of the earth's formation by inhomogeneous accretion. (CaO, pressure, EOS, mantle).
Geophys. Res. Lett., Paper 80L1735

Planetology

6810 Atmospheres of planets
EQUATORIAL ANOMALY IN THE JOVIAN IONOSPHERE
A.K. Mahajan (National Physical Laboratory, New Delhi, 110 012, India)

The electron concentration data from Pioneer 10 and 11 and Voyager 1 and 2 indicate the presence of equatorial anomaly in the Jovian ionosphere, with the peak electron concentration value showing a minimum near the equator. (Pioneer 10 and 11, Voyager 1 and 2, equatorial anomaly, Jovian ionosphere).
Geophys. Res. Lett., Paper 80L1724

6520 Surface (first km) of moon
ICE IN THE POLAR REGIONS OF THE MOON
L. J. Lanzerotti (Bell Laboratories, Murray Hill, N.J., 07974), W. L. Brown, and R. E. Johnson

Recent laboratory measurements of the erosion of H_2O ice are used to estimate the loss rates of possible trapped "volatiles" in the cold lunar polar regions. We conclude that a significant accumulation of water ice is unlikely to occur. (Moon, sputtering, ices).
J. Geophys. Res., Red, Paper 80B1715

Seismology

Solar Physics, Astrophysics, and Astronomy

... inferred from the DPA data.
J. Geophys. Res., Blue, Paper [illegible]

Tectonophysics

8150 Plate tectonics
NONUNIFORM SEISMIC SLIP RATES ALONG THE MIDDLE AMERICA TRENCH
Karen C. McNally (Seismological Laboratory, California Institute of Technology, Pasadena, California 91125) J. Bernard Minster

Revised estimates of seismic slip rates along the Middle America Trench are lower than plate convergence rates on the average, but match them locally (e.g., Oaxaca). Along the Cocos-North America plate boundary, this can be explained by nonuniformities in slip at points of aseismic ridge or fracture zone subduction. For at least 81 years (and possibly several hundred years) no major ($M_s \geq 7.5$) shallow earthquake is known to have occurred near the Orozco Fracture Zone and Tehuantepec Ridge areas. Comparison with the average recurrence periods for large earthquakes of 33 ± 8 y. since 1898 and 35 ± 24 y. between 1542 and 1979 suggests that either a large ($M \geq 8.4$) event may be anticipated at such locations, or that these are points of aseismic subduction. At least three marine terraces of probable recent age are found on the coast near the Orozco Fracture zone, which may point to large infrequent earthquakes. The larger discrepancy between plate convergence and seismic slip rates along the Cocos-Caribbean plate boundary is more likely due to decoupling and downbending of the subducted plate.

We use the limited statistical evidence available to characterize both spatial and temporal deficiencies in recent seismic slip. The observations appear consistent with a possible forthcoming episode of more intense seismic activity. Based on a series of comparisons with carefully delineated aftershock zones, we conclude that the zones of anomalous seismic activity can be identified by a systematic, automated analysis of the worldwide earthquake catalog ($M_s \geq 4$).
J. Geophys. Res., Red, Paper 80B1713

Volcanology

8497 Volcanology topics
POSSIBLE TERRESTRIAL VOLCANIC OCCURRENCES OF GAS CLATHRATE HYDRATES